WAIMEA WASTEWATER TREATMENT PLANT EFFLUENT REUSE/DISPOSAL ALTERNATIVE STUDY

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PREPARED FOR:

COUNTY OF KAUAI
Department of Public Works

PREPARED BY:

Austin, Tsutsumi & Associates, Inc.
Civil Engineers • Surveyors
Honolulu • Wailuku • Hilo, Hawaii

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TABLE OF CONTENTS

		Page
i.	EXECUTIVE SUMMARY	1-3
IJ.	INTRODUCTION	4-5
111.	BACKGROUND	6-10
	A. Property Ownership and Land Ownership B. Climate	6-7 7-8 8-9 9-10 10
IV.	DESCRIPTION OF EXISTING WASTEWATER SYSTEM	11-17
	A. Wastewater Collection/Transmission	11-13 13-17 17
V.	DESCRIPTION OF EXISTING IRRIGATION SYSTEMS	18-19
	A. Sugar Cane	18 19 19
VI.	DEPARTMENT OF HEALTH REQUIREMENTS	20-30
	A. Underground Injection of Effluent	20-22 22-29 29-30
· VII.	EVALUATION CRITERIA	31-35
	A. Treatment Efficiency	31 31-32 32 32-33
	E. Land Issues	34

TABLE OF CONTENTS (Continued)

			Page
VII.	EVAL	UATION CRITERIA (Continued)	
	F. G. H.	Cost	34 34-35 35
VIII.	DESC	CRIPTION OF ALTERNATIVES	· 36-63
	A. B. C. D.	Renegotiation of Kikiaola/County Agreement Underground Injection Reclamation Other Alternatives	36-40 40-61 61-63
IX.	CON	CLUSIONS AND RECOMMENDATIONS	64-70
	A. B. C. D.	Renegotiation of the Current Disposal Agreement	64-65 65 65-66
	E. F. G.	Irrigation Reuse for Crops or Pastures	66-68 68 68-70
TABL	<u>ES</u>		
1	SUM ALTE	MARY OF EFFLUENT REUSE/DISPOSAL	3
2	LANE	USE CLASSIFICATIONS	7
3	MEA EVA	N MONTHLY PRECIPITATION AND PAN PORATION DATA AT STATION 944.00	8
4	TREA	ATMENT PLANT DESIGN DATA	15
5	CUR OF II	RENT FLOW RATES AND CHEMICAL CHARACTERISTICS NFLUENT WASTEWATER AND OF EFFLUENT	16
6	GBA	R SAMPLE ANALYSIS FOR NUTRIENTS	16

TABLE OF CONTENTS (Continued)

		<u>Page</u>
7	SUMMARY OF SUITABLE USES FOR RECLAIMED WATER	23-25
8	ESTIMATED CONSTRUCTION COST FOR INJECTION WELL	39
9	WATER BALANCE FOR SCENARIO 1 @ 300,000 GPD	44
10	WATER BALANCE FOR SCENARIO 1 @ 600,000 GPD	45
11	WATER BALANCE FOR SCENARIO 2 @ 300,000 GPD	46
12	WATER BALANCE FOR SCENARIO 2 @ 600,000 GPD	47
13	WATER BALANCE FOR SCENARIO 3 @ 300,000 GPD	48
14	WATER BALANCE FOR SCENARIO 3 @ 600,000 GPD	49
15	WATER BALANCE FOR SCENARIO 4 @ 300,000 GPD	50
16	WATER BALANCE FOR SCENARIO 4 @ 600,000 GPD	51
17	ESTIMATED CONSTRUCTION COST FOR MODIFICATION OF LOWER RESERVOIR	57
18	ESTIMATED CONSTRUCTION COST FOR SCENARIO 1 - IRRIGATION SYSTEM WITH CROPS MAUKA OF HIGHWAY AND PASTURES MAKAI OF HIGHWAY	58
19	ESTIMATED CONSTRUCTION COST FOR SCENARIO 2 - IRRIGATION SYSTEM WITH SEED CORN MAUKA OF HIGHWAY AND PASTURES MAKAI OF HIGHWAY	59
20	ESTIMATED CONSTRUCTION COST FOR SCENARIO 3 - IRRIGATION SYSTEM WITH PASTURES MAUKA AND MAKAI OF HIGHWAY	60

TABLE OF CONTENTS

(Continued)

		<u>Page</u>
TAB	LES (Continued)	
21	ESTIMATED CONSTRUCTION COST FOR SCENARIO 4 - IRRIGATION SYSTEM WITH TURF MAKA! OF HIGHWAY AT WAIMEA PARK	61
22	SUMMARY OF ESTIMATED CONSTRUCTION COSTS	68
EXH	BITS	
1	LOCATION MAP	
2	SITE MAP	
3	TAX MAP	
4	SOIL TYPES IN PROJECT AREA	
5	FLOOD MAP	
6	EXISTING WAIMEA WASTEWATER SYSTEM	
7	WAIMEA WWTP SITE PLAN	
8	WAIMEA WWTP HYDRAULIC PROFILE	
9	WWPS 'A' SITE PLAN	
10	PROPOSED IRRIGATION REUSE AREAS	

TABLE OF CONTENTS

(Continued)

APPENDICES

- A Mink & Yuen, Inc.'s "Waste Water Effluent Disposal by Injection Wells", August 1993
- B Excerpts from U.S. Soils Conservation Service's "Soil Survey of Islands of Kauai, Oahu, Maui, Molokai and Lanai, State of Hawaii", August 1972
- C Belt Collins & Associates' "Engineering Study for Kikiaola Master Plan", July 26, 1990
- D Letter from U.S. Environmental Protection Agency to the Hawaii Department of Health dated October 4, 1993
- E Correspondence Between Austin, Tsutsumi & Associates, Inc. and Hawaii Department of Health



CONTINUING THE ENGINEERING PRACTICE FOUNDED BY H. A. R. AUSTIN IN 1934

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WAIMEA WASTEWATER TREATMENT PLANT

EFFLUENT REUSE/DISPOSAL ALTERNATIVE STUDY

I. EXECUTIVE SUMMARY

Alternatives for effluent reuse/disposal from the County of Kauai's (County) Waimea Wastewater Treatment Plant (WWTP) were evaluated. This report was prepared as a result of the pending expiration of the following two lease agreements:

- A lease agreement between Kikiaola and Kekaha Sugar Company (Kekaha) for cultivation of sugar cane by Kekaha on Kikiaola land. This lease expires on December 31, 1993.
- An agreement between Kikiaola and the County for discharge of effluent from the Waimea WWTP into Kikiaola's irrigation reservoir. This agreement expires on December 31, 1994.

Reuse alternatives that were evaluated include using effluent for irrigation of four different vegetation; (1) sugar cane, (2) seed corn, (3) pasture and (4) turf — either for a golf course or at Waimea Park. Disposal alternatives that were studied include effluent disposal via, (1) underground injection wells, or (2) an ocean outfall. Approximate construction costs were calculated for all the alternatives except for golf course irrigation, which would be a future solution. A summary of the alternatives evaluated is presented in Table 1.

Based on the cost and subjective factors in Table 1, it is recommended that injection wells, for disposal of effluent from the Waimea WWTP, be pursued by the County. The injection wells would be located on land owned by the County, at the site of the existing Wastewater Pump Station 'A'.

Kikiaola, in the near future, is planning on developing the land on which their irrigation reservoir is located. Therefore, one injection well would be required when the reservoir becomes unavailable. The well would be the backup disposal system (instead of the reservoir) if effluent reuse is continued. This well should have a capacity of 1.2 mgd, which could handle the peak flow rate for the future WWTP capacity of 600,000 gpd. This peak flow rate is based on a documented peak to average flow factor of 2.0.

If effluent reuse is eliminated all together, then a second 1.2 mgd capacity well would be required to provide for a 100 percent backup system for the future WWTP capacity.

The County should file a UIC Application Permit with the State for construction of two injection wells, each with a capacity of 1.2 mgd, as soon as possible.

TABLE 1. SUMMARY OF EFFLUENT REUSE/DISPOSAL AL

		·	·, ··				
ALTER- NATIVE	DESCRIPTION	4	ESTIMATED CONSTRU COST (\$1;000) MAJOR WORK	ICTION:	ADVANTAGES		
"A"	Renegotiation of the Current E Agreement)isposal	Modify existing lower effluent reservoir	\$380	Least costly of all alternatives. Beneficial reuse of the effluent.	:	
"B"	Golf Course Irrigation		N/A	N/A	 Beneficial reuse of the effluent. May be a long-term solution in the future. 	•	
"C"	Ocean Outfall		Construct ocean outfall.	\$10,000	 No agreements between the County and Kikiaola required (other than pipeline easement). Lowest O&M cost of all alternatives. 	•	
D	Subsurface Disposal Via Injecti Reclamation)	on Wells (No	 Construct two injection wells. Install effluent transmission line. 	\$760	 No agreements between the County and Kikiaola required, since Injection wells would be located on County property. Can be implemented quicker than reuse alternatives. Less expensive than all alternatives except "A". 	•	
E	Effluent Reuse With storage reservoir.		 Modify lower reservoir. Install drip irrigation system. 	\$1,360*	Beneficial reuse of the effluent.		
"F"	highway, pasture makai of the highway . Scenario 1	With injection well.	 Construct one injection well. Install drip irrigation system. 	\$1,390*	Alternative "E" is least expensive reuse alternative	•	
" G"	Effluent Reuse Seed com mauka of the	With storage reservoir.	 Modify lower reservoir. Install drip irrigation system. 	\$1,480*	Beneficial reuse of the effluent.	•	
"H"	highway, pasture makai of the highway Scenario 2 With injection well.		 Construct one injection well. Install drip irrigation system. 	\$1,510*	Kikiaola will most likely lease their land to seed corn growers.	•	
* *	Effluent Reuse	With storage reservoir.	Modify lower reservoir. install drip irrigation system.	\$1,580*	Beneficial reuse of the effluent. Pasture /tur/ has bigher evapotranspiration.		
٠٦.	Pasture mauka and makal of highway Scenario 3	 Construct one injection well. Install drip irrigation system. 	. \$1,610*	 Pasture/turf has higher evapotranspiration rate than sugar cane and seed corn, and thus, more effluent can be used. 			

^{*} Cost does not include upgrading the WWTP to provide R-1 quality water.

ENT REUSE/DISPOSAL A	ILIERNA IIVES
	REIEIMANI CO
ADVANTAGES	DISADVANTAGES
of all alternatives. use of the effluent.	 Not likely to be long-term solution. Requires modification of existing reservoir at present time.
use of the effluent. ng-term solution in the future.	 Requires implementation of Kikiacia's Master Plan. Requires supplemental study on further expansion of the WWTP and the effluent/disposal system. Requires new agreement between the County and Kikiacia. Kikiacia would require R-1 quality water.
nts between the County and uired (other than pipeline cost of all alternatives.	 Very expensive. Not a beneficial reuse of the effluent.
ints between the County and ulred, since injection wells cated on County property. Itemented quicker than reuse sive than all alternatives except	Not a beneficial reuse of the effluent.
use of the effluent. E" is least expensive reuse	 Not likely to be long-term solution. Kikiaola will probably not renew lease with Kekaha, so sugar cane may not be cultivated. Requires renegotiation of existing, or new, agreement with Kikiaola. If lower reservoir is used for backup, then dependent upon design monthly percolation ra (DMPR) included in water balance calculations. Not enough storage available if DMPR is excluded. County would be responsible for tubing within irrigated crop areas. Kikiaola would require R-1 quality water.
use of the effluent. most likely lease their land to rowers.	 Not likely to be long-term solution. Requires renegotiation of existing, or new, agreement with Kikiaola. If lower reservoir is used for backup, then dependent upon design monthly percolation ra (DMPR) included in water balnes calculations. Not enough storage available if DMPR is excluded. County would be responsible for tubing within irrigated crop areas. Kikiaola would require R-1 quality water.
use of the effluent. thas higher evapotranspiration par cane and seed corn, and tilluent can be used.	 Not likely to be long-term solution. Requires renegotiation of existing, or new, agreement with Kikiaola. More expensive than all other alternatives, except for "C". County would be responsible for tubing within irrigated areas. Kikiaola would require R-1 quality water.

II. INTRODUCTION

The purpose of this study is to determine the feasibility of the following alternatives, or combinations thereof, for reuse/disposal of effluent from the County of Kauai's (County's) Waimea Wastewater Treatment Plant (WWTP):

- Renegotiation of the current disposal agreement between the County and Kikiaola Land Company (Kikiaola).
- Subsurface disposal via injection wells.
- Irrigation reuse on crops, landscaping/turf or pastures.
- Irrigation reuse on a golf course proposed as part of Kikiaola's Master Plan for the area.

The terms "reclaimed water" and "effluent", and "reclamation" and "reuse", are used somewhat interchangeably throughout this study. The intended differentiation is that reclaimed water is effluent that is reused for some beneficial purpose — in this study, for irrigation. Although physically the same, effluent, rather than reclaimed water, is treated wastewater that is discharged into injection wells.

The urgency of this study is predicated on the expiration of the following two agreements - both of which may possibly not be extended, due to Kikiaola's Master Plan for the study area:

- A lease agreement between Kikiaola and Kekaha Sugar Company (Kekaha) for cultivation of sugar cane by Kekaha on Kikiaola land. This lease expires on December 31, 1993.
- An agreement between Kikiaola and the County for discharge of effluent from the Waimea WWTP into Kikiaola's irrigation reservoir. This agreement expires on December 31, 1994.

The flow rates to be considered for this study are the current design capacity of the WWTP - 300,000 gallons per day (gpd) - and the "ultimate" expanded capacity of 600,000 gpd. As a matter of clarification, the future capacity of 600,000 gpd was

established in the early 1970's, and hence, does not consider flows expected to be generated from the recently prepared Kikiaola Master Plan. Therefore, a premise of this study is that implementation of the Kikiaola Master Plan will require a supplemental study on further expansion of not only the treatment capacity of the WWTP, but also of the effluent reuse/disposal system.

Related to this study is a separate Wastewater Facility Plan for the Waimea WWTP, which is currently being prepared. This Facility Plan will evaluate in detail the expansion of the WWTP from 300,000 to 600,000 gpd. Therefore, it is not in the scope of this reuse/disposal study to address the technical issues related to expansion of the WWTP or upgrading of treatment efficiency. However, a general discussion on required effluent quality for implementation of a successful reuse/disposal system is included in this study.

It is also not within the scope of this study to incorporate a Basis of Design Report, pursuant to the State Department of Health's (DOH's) guidelines for water reclamation. However, the primary issues of these guidelines are addressed to formulate a basis for potentially proceeding into this next step for implementation of a reuse plan.

The main text of this report includes - besides basic background information - an evaluation of the reuse alternatives. The alternative of disposal of effluent via injection wells is evaluated in Mink & Yuen, Inc.'s report, included as Appendix A. Conclusions and recommendations from Mink's report, however, have been extracted for inclusion into the final sections of the main text.

Also included for reference, as appendices to this report, are the following:

- Excerpts from the U.S. Soils Conservation Service's Soil Survey (Appendix B).
- The July 26, 1990 draft of Belt Collins & Associates' "Engineering Study for Kikiaola Master Plan" (Appendix C).
- A letter from the U.S. Environmental Protection Agency to DOH (Appendix D).
- A letter from Austin, Tsutsumi & Assoc. Inc. to DOH, and DOH's response letter (Appendix E).

III. BACKGROUND

A. Property Ownership and Land Ownership

The study area is located in the Waimea-Kekaha region on the southwestern portion of the island of Kauai. The study area is focused primarily on land which may be used for effluent reuse, namely, properties owned by Kikiaola and the County. (See Exhibits 1, 2 and 3.) The majority of the land area is owned by Kikiaola (Tax Map Keys: TMK: 1-2-06:3, 9, 41 and 42). Land owned by the County is limited to the sites for the Waimea Wastewater Treatment Plant (WWTP) (TMK: 1-2-06:36) and Wastewater Pumping Station (WWPS) 'A' (TMK: 1-2-06:37). Parcel 9, the 400 ± acre area mauka of Kaumualii Highway, is presently being leased to Kekaha by Kikiaola.

The portion of the study area mauka of Kaumualii Highway consists primarily of cultivated sugar cane fields and a small area of cultivated seed corn. The fields are divided by dirt cane haul roads and drainage ditches.

Parcel 42, the 42 acre area makai of the highway, is presently the site of a small resort development owned by Kikiaola called Plantation Cottages. Parcel 3 is presently being leased to Northrup King Co. for seed corn cultivation, and the remaining portion of the study area makai of the highway consists primarily of wasteland with grass and shrubs.

Land uses of property adjoining the study area include residential, government and agricultural activities. Kekaha is presently raising sugar cane on land leased from Augustus Knudsen along the western boundary of the area (Parcel 6). On the eastern boundary is Waimea Town, and State-owned land utilized for Waimea Elementary and Intermediate School (Parcel 33) and Waimea Park (Parcel 38). The Pacific Ocean constitutes the southern boundary of the project area, while to the north is the sloping lower mountains which extend northward to Kokee.

The State Land Use Commission and the County Planning Department have different land use classifications for the different parcels of the study area. (See

Table 2 for a brief summary.) The Conservation areas of Parcels 3 and 41 are along the shoreline.

TABLE 2. LAND USE CLASSIFICATIONS

	LAND USE (CLASSIFICATION
PARCEL NUMBER	State Land Use Commission	County of Kauai, Planning Department
3	Agricultural Conservation Urban	Project District
9	Agricultural	Project District
41	Agricultural Conservation	Project District; Open
42	Urban	Project District; Open

B. Climate

Temperatures in the Waimea-Kekaha region range from the mid 50's to the low 90's (degrees Fahrenheit), with an average temperature of 75°F. Average daily temperatures vary by about ten degrees between winter and summer and about 15 to 18 degrees between day and night.

Mean annual rainfall recorded at Station 944.00 from 1916 to 1983 amounted to 21.77 inches. (See Exhibit 2 for location of Station.) The distribution of rainfall from month to month varies from heavy rainfalls at times to very light at others. Winter months typically have the most rainfall.

The mean annual pan evaporation recorded at Station 944.00 from 1960 to 1983 amounted to 73.53 inches. Summer months typically have the highest evaporation rates.

Table 3 summarizes the mean monthly precipitation and pan evaporation for Station 944.00. It should be noted that even during the rainy winter months, the

evaporation rates exceed the precipitation rates. This climatological condition is ideal for an irrigation reuse program.

TABLE 3. MEAN MONTHLY PRECIPITATION AND PAN EVAPORATION AT STATION 944.00

MONTH	PRECIPITATION ⁽¹⁾ (inches)	PAN EVAPORATION ⁽²⁾ (inches)
January	4.17	4.54
February	2.48	4.98
March	2.44	6.31
April	1.42	6.67
May	0.98	7.07
June	0.47	7.29
July	0.51	7.59
August	0.75	7.55
September	0.79	6.82
October	1.89	5.96
November	2.13	4.89
December	3.70	4.15
ANNUAL	21.77	73.53

- (1) From "Rainfall Atlas of Hawaii", Report R76, State of Hawaii Department of Land and Natural Resources, June 1986. Years of data include: 1916 to 1983.
- From "Pan Evaporation: State of Hawaii, 1894-1983", Report R74, State of Hawaii, Department of Land and Natural Resources, August 1985. Years of data include: 1960 to 1983.

C. Topographic Features

The study area lies on part of the Mana Plain, which is characterized by generally flat slopes, with elevations ranging from sea level at the shoreline to about 30 feet mean sea level (msl) at the northern (mauka) boundary. The

elevation at the WWTP, approximately 1000 feet mauka of the highway, is about 6 feet msl.

The watershed area mauka of the study area rises abruptly around the 50-foot elevation with slopes of 5 to 35 percent, and up to 80 percent along the steep valley walls. Elevations vary from about 200 feet msl to 1300 feet msl at the upper boundary of the watershed.

D. Geology and Soils

The study area is comprised of a sequence of sedimentary strata (cap rock) resting on the basement rock of Napali basalt. The caprock varies in depth from 310 feet thick at the Waimea WWTP to 400 feet thick near the Kekaha Sugar Mill. The caprock sediments as a whole are poorly permeable and act as a confining layer on the Napali aquifer. (See Appendix A for additional information.)

General soil classifications were published by the U.S. Soils Conservation Service (SCS) for the Islands of Oahu, Kauai, Maui, Molokai, Lanai and Hawaii, in 1972. (See Exhibit 4.) Brief descriptions of the soils, as well as general physical properties, are provided in the SCS surveys. (See Appendix B.)

The portion of the study area which lies mauka of Kaumualii Highway consists mainly of Kekaha Series soils classified as clay, silty clay and stony silty clay loam. These series consist of well-drained soils with moderate permeability and zero to moderate erosion hazard. There are also areas of Nohili and Kaloko clay, which consist of poorly drained soils with moderately slow to slow permeability and zero to slight erosion hazard.

The area between the Underground Injection Control (UIC) Line and the highway is mostly filled land, which consists primarily of bagasse and slurry from sugar mills. This land type is not in a capability classification. Therefore, permeability and the amount of erosion are not provided by the SCS. However, information obtained from Kekaha indicates that the soil consists of a poorly drained, heavy clay, with a depth ranging from 3 to 6 feet.

Soils make of the highway are mostly classified as Jaucaus loamy fine sand. These series consist of excessively drained, calcareous soils with rapid permeability and slight erosion hazard.

E. Floods and Tsunamis

The National Flood Insurance Program publishes Flood Insurance Rate Maps for the State of Hawaii which designate areas of flood hazard. (See Exhibit 5.) A large portion of the study area mauka of Kaumualii Highway (including the WWTP and WWPS 'A' sites), and a small area near the coast, are in a Special Flood Hazard Area inundated by 100-year floods with base flood elevations of eight and nine feet, respectively. Another portion of the study area makai of the highway is classified as Zone X, which is in an area of 500-year flood and/or an area of 100-year flood with average depths of less than one foot. The remaining portion of the study area mauka of the highway, and the area directly makai of the highway, are outside of the 500-year flood plain.

A small strip of land along the coastline is designated as Zone VE, which is a coastal flood area with velocity hazard (due to tsunami wave action) with base flood elevations of nine feet.

IV. DESCRIPTION OF EXISTING WASTEWATER SYSTEM

Before the existing Waimea wastewater system was installed, wastewater was disposed of by individual wastewater systems (i.e., cesspools and septic tanks). Due to the low ground elevation and high groundwater table of much of the urbanized area of Waimea, sewage routinely overflowed from these systems.

Cesspools were also located on the steeper slopes of Waimea Heights. Seepage water from these cesspools struck the impervious layer of old lava flows and the vertical seep was deflected laterally to such a degree that wastewater appeared on the ground surface adjacent to, as well as below the bottom of, the cesspool. This led to algae growths and foul odors.

Because of the problems of overflowing cesspools, future development was denied until wastewater treatment was provided.

In 1971, a report titled, "Preliminary Engineering Study of Sewerage and Sewage Disposal for the Waimea Town Area, Kauai, Hawaii", was prepared by Austin, Smith & Associates, Inc. (presently Austin, Tsutsumi & Associates, Inc.). This report addressed the need for a wastewater system for Waimea. The total area studied in the report was 400 acres and was bounded on the south by the Pacific Ocean, and on the east, by the Waimea River. To the north were the sloping lower mountains which extend northward to Kokee, and to the west were irrigated sugar cane lands. At the time of the report, 200 acres were urbanized or partially developed.

The following sections describe the wastewater system that was constructed for Waimea Town to eliminate the previously mentioned problems.

A. Wastewater Collection/Transmission

The wastewater collection and transmission system for Waimea is comprised of gravity lines, wastewater pump stations (WWPSs) and force mains. The existing wastewater collection system for Waimea was constructed in four phases. The first phase was constructed in 1972 and the second phase, which sewered the Central Waimea Area, immediately followed in 1973. The Waimea Heights Area was

sewered in 1980 and the Waimea Valley Area, shortly after in 1983. Exhibit 6 shows the existing Waimea wastewater system. A brief description of the four phases follows.

Phase I -- The wastewater collection system for Phase I consists of a gravity line, force mains and a pump station (WWPS 'A'). WWPS 'A' is an underground package station with a separate wet well. The pre-fabricated underground "tank" is covered on the exterior with fiberglass to resist corrosion from the brackish water.

WWPS 'A' is located on the mauka edge of Kaumualii Highway along the road to the WWTP. The station lifts all the wastewater from the sewered areas of Waimea to the WWTP and is designed for an average wastewater flow of 210 gallons per minute (gpm) and a peak flow of 850 gpm.

The Waimea WWTP and the 10-inch effluent force main to the effluent reservoirs were also constructed during this phase.

Phase II (Central Waimea Area) — The wastewater collection system for Phase II sewered the Central Waimea Area and a portion of the land mauka of Kaumualii Highway. A second pump station (WWPS 'C'), similar to WWPS 'A', was also constructed.

WWPS 'C' conveys wastewater from approximately 30 acres makai of Kaumualii Highway, between the old pier and the west edge of town. The station is designed for an average wastewater flow of 50 gpm and peak flow of 275 gpm.

Phase III (Waimea Heights Area) -- The Heights Area of Waimea Town is at the southwest base of Kauai's two major mountains, Mt. Kawaikini and Mt. Waialeale. A steep cliff on the eastern edge separates the Heights and Waimea Valley Areas. The central area of Waimea Town lies immediately below the Heights and the western edge is bordered by cane fields.

The wastewater collection system for the Waimea Heights Area consists of approximately 6300 lineal feet of 8-inch gravity lines. The collection system for Waimea Heights connects to the system installed during Phase II at two locations near Huakai Road.

Phase IV (Waimea Valley) -- The Waimea Valley Area is located off the northwest bank of Waimea River at an elevation ranging from 5 to 15 feet msl. The wastewater collection system is comprised of two pump stations (WWPS No. 1 and WWPS No. 2) and approximately 9500 lineal feet of 12-inch and 8-inch gravity lines. The pump stations are constructed of cast-in-place concrete wet wells with submersible pumps. The collection system connects to the sewer system from Phase II at two points, in Menehune Road and in Waimea Road.

B. Wastewater Treatment

In 1968, State and Federal laws required that tertiary treatment of wastewater or long ocean outfalls were required for discharge of effluent into the ocean. Meeting these requirements would have been very costly, so a more economical means of disposal was sought. The Waimea WWTP, constructed in 1972, was designed for secondary treatment utilizing extended aeration and chlorination of the effluent. The chlorinated effluent would combine with storm water and then be used for irrigation. Chlorination would kill the coliform bacteria and the nutrients remaining in the effluent would be used by sugar cane. Secondary treatment also provided for the stabilization of the raw sewage by removing the biochemical oxygen demand and suspended solids.

The Waimea WWTP, located on the eastern edge of the sugar cane lands of Kikiaola, was determined to be the best point to serve Waimea Town, as well as any future development by Kikiaola. Two existing large reservoirs, located above the cane fields, were used to hold the effluent, where it was combined with storm water, before being dispersed for irrigation.

The first phase of the treatment plant was designed for an average wastewater flow of 272,000 gallons per day (gpd). The WWTP included a standard two-tank system with a capacity of 300,000 gpd, which allowed for a 10% increase in wastewater flow. The two tanks allowed for partial treatment of the wastewater during emergencies when one tank might be taken off-line.

Treatment process of the wastewater includes comminuting and degritting, aeration, final settling and then chlorination. The chlorinated effluent is then pumped to the effluent reservoirs. The sludge is routed to the aerated sludge holding tank, for stabilization, and subsequently pumped to the sludge drying beds for dewatering. Exhibits 7 and 8 show the existing Waimea WWTP site plan, and the Waimea WWTP hydraulic profile, respectively. Design data for the existing WWTP are presented in Table 4.

The future wastewater flow from the Waimea area was estimated to be 422,000 gpd. Allowances were made for future expansion of the WWTP of up to 600,000 gpd to accept future flows from Waimea — as well as wastewater flows from Kekaha Town, which lies less than three miles from the Waimea WWTP. This could be accomplished by installing two more tanks at 150,000 gpd capacity, each. Theoretically, the Waimea WWTP could be expanded to 900,000 gpd by enriching the oxygen supply in the compressed air, should it ever become necessary. However, as of June 1993, the wastewater flow rate has not exceeded 300,000 gpd and, therefore, expansion of the existing Waimea WWTP has not been necessary.

The wastewater treatment plant was designed in accordance with the ASCE - WPF Manual 36 on "Sewage Treatment Plant Design" and the Ten States Standards. The plant was also designed to meet practical requirements of the State and Federal Water Quality Administration Standards.

TABLE 4. TREATMENT PLANT DESIGN DATA

DESIGN POPULATION	3,000	
DAILY SEWAGE FLOW PER CAPITA	100	gpd
DESIGN DAILY FLOW	300,000	gpd
DESIGN AVERAGE FLOW RATE	208	gpm
DESIGN MAXIMUM FLOW RATE (PUMP CAPACITY)	1,050	gpm
DESIGN RAW SEWAGE BIOCHEMICAL OXYGEN DEMAND (B.O.D.)	250 625	mg/l #/day
DESIGN RAW SEWAGE SUSPENDED SOLIDS (S.S.)	200 510	mg/l #/day
AERATION TANKS:		
DETENTION TIME (TOTAL)	24	hours
VOLUME OF AIR	2,000 870	cf/#BOD cfm
SETTLING TANKS:		
SURFACE SETTLING RATE	<600	gal/sf/day
WEIR OVERFLOW RATE	<7,000	gal/f/day
RECIRCULATION RATE	>1	to 1
FINAL CLARIFIER DETENTION	>4	hrs.
VOLUME OF AIR (SLUDGE HOLDING TANK)	90	cfm
VOLUME OF HOLDING TANK	3,000	
B.O.D. REMOVAL	90	<u> </u>
B.O.D. IN CLARIFIER EFFLUENT	25	mg/l
AVERAGE CHLORINE DOSAGE	8	- 10 mg/l
CHLORINE USAGE	25	- 26#/day
CHLORINE CONTACT TIME	30	min. +
OVERALL EFFICIENCY	93	%

Current conditions, and performance, of the WWTP are summarized in Table 5. The average effluent flow rate ranged from a minimum of 209,000 gpd to a maximum of 274,000 gpd, with a median of 247,000 gpd, during the period of January 1992 through April 1993. The effluent is of high quality with both the Biochemical Oxygen Demand (BOD) and the Total Suspended Solids (TSS) well below 10 mg/l, and most of the time, below 5 mg/l.

The peak day flow rate over the past three years was 525,000 gpd, which occurred on October 4, 1991. This suggests that a peak day factor of 2.0 would be appropriate for current conditions.

In addition to these regularly analyzed parameters, a recent grab sample was analyzed for nutrient concentration. (See Table 6 for the results of this analysis.) The results are typical of a secondary treatment plant receiving domestic wastewater.

TABLE 5. CURRENT FLOW RATES AND CHEMICAL CHARACTERISTICS OF INFLUENT WASTEWATER AND EFFLUENT

	83,4536	e de la companya de l	n cates	2000		19	92		9.998		(0.84)			1.0	93	
PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	ำกา	AUG	SEP	ОСТ	NOV	DEC	JAN	(FEB)	MAR	APR
FLOW Influent (mgd) Effluent (mgd)	.243 .258	.244 .247	.237 .250	.226 .245	.248 .274	.237 .250	.240 .251	.252 .261	.217 .232	.212 .245	.218 .209	.216 .241	.209 .222	.210 .235	,202 ,222	.232 .255
BOD Influent (mg/l) Effluent (mg/l)	212 2.5	211 2.5	167 3.0		146 1.5		114 3.5			147 0.8	157 2.2	219 2.6		86 0.9	116 0.9	334 5.2
TSS influent (mg/l) Effluent (mg/l)	134 6.7	153 ຮ.9	163 4.6	124 2.5	126 4.1	155 5.4	173 4.8			173 4.6		96 3.7	170 4.4	141 3.4	163 4.4	348 3.2
TOTAL COLIFORM (count per 100 ml)	2	2	3	3	7	5	5	6	12	8	6	6	3	4	2	2
CHLORINE RESIDUAL (ppm)	2 1.0	1.1	1.1	1.2	1.3	1.3	1.3	1.3	1.0	2.2	1.1	2.1	2.0	2.4	2.5	1.4

TABLE 6. GRAB SAMPLE ANALYSIS FOR NUTRIENTS

ITEM	INFLUENT	EFFLUENT
Total Kjeldahl Nitrogen	34.7 mg/l	.058 mg/l
Inorganic Nitrogen	.007 mg/l	20.4 mg/l
Total Nitrogen	34.8 mg/l	21.0 mg/l
Phosphorus	5.13 mg/l	0.58 mg/l
Ortho Phosphate	3.15 mg/l	2.70 mg/l
Turbidity		3.50 NTU

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According to County records, there are only 72 houselots in Waimea — of which 62 lots are still vacant — that have yet to hook up to the County system. Based on $400 \pm \mathrm{gpd}$ per lot, the additional flow from these lots would be 29,000 gpd, which suggests a "build-out" median average flow (without the Kikiaola Master Plan) of 270,000 — 280,000 gpd.

C. Effluent Reuse/Disposal

The chlorinated effluent from the WWTP is pumped, via a 10-inch force main, to two large reservoirs located above the cane fields near the Waimea Heights Area. The effluent can be routed to either the "upper" or the "lower" reservoir by a manually operated valve. The volumes of the upper and lower reservoirs are approximately 10 million gallons (MG) and 8 MG, respectively.

Presently, a large portion of the storm water runoff, from the drainage basin mauka of the study area, is intercepted by a network of irrigation ditches and dispersed throughout the cane fields. Some of the storm water that enters Kekaha Ditch is routed to the upper reservoir, and then released into the lower reservoir via a slide gate. The lower reservoir can also be supplemented by a water well located approximately 2,300 feet makai of the lower reservoir. This well also pumps storm water runoff and excess irrigation water from the surrounding sugar cane fields.

The effluent is released from the lower reservoir into an irrigation ditch, and from there dispersed to the nearby sugar cane fields for irrigation.

The current practice is to pump the effluent primarily into the lower reservoir, and to isolate storm water from entering this reservoir from the upper reservoir, via closure of the slide gate. Presently, all the effluent is being used by Kekaha for irrigation of sugar cane, and by DeKalb Plant Genetics for irrigation of seed corn.

V. DESCRIPTION OF EXISTING IRRIGATION SYSTEMS

Currently, there are three different land uses in the vicinity of the Waimea WWTP which use various forms of irrigation. The three uses are for production of sugar cane, seed corn, and landscaping/turf. A brief description of the existing irrigation system for each of these land uses follows.

A. Sugar Cane

Kekaha is presently leasing from Kikiaola approximately 400 acres of land adjacent to the WWTP for cultivation of sugar cane. Approximately 250 acres of this land, lying above the UIC Line, is irrigated with mountain water from Kekaha Ditch via a drip irrigation system. The drip irrigation system is a low pressure system and, therefore, does not require pumping.

Approximately 160 acres of sugar cane land, which lies below the UIC Line, is irrigated with effluent from the reservoirs, via surface irrigation.

There are no sprinkler systems and the irrigation water is conveyed to the sugar cane fields primarily by irrigation ditches.

A typical sugar cane cultivation schedule is approximately 20 months. The sugar cane is fertilized for the first 12 months, with no fertilization during the last eight months. At the start of the crop cycle, the sugar cane is irrigated one day every 10 to 15 days at a rate of three-acre-inches. As the crop matures, irrigation is decreased to about every 20 days, at the same rate. The last two months of the crop cycle are fallow (i.e., no irrigation during this time).

The start of the sugar cane crop cycles are staggered, such that 60 to 70 percent of the crops are irrigated throughout the year. Consequently, the average sugar cane irrigation consumption is approximately 1.0 million gallons per day (mgd) per 100 acres. About half of the crops are harvested every year.

B. Seed Corn

DeKalb Plant Genetics leases approximately 23 acres of land from Kikiaola near the WWTP for cultivation of seed corn, of which approximately 15 acres are planted each season. The present irrigation system utilizes effluent/storm water from the lower reservoir with a sprinkler system at 50-60 pounds per square inch (psi) of head. Since the Waimea soils are fairly heavy (i.e., it holds water well), the current irrigation rate is once a week at 3/4-inch to 1-inch, which corresponds to approximately 0.70 mgd per 100 acres. The normal procedure is to soak the ground well in October and November and then taper off irrigation. Due to a corn virus which effects the west side of Kauai, a voluntary "corn-free" period is implemented, during which time the corn is not irrigated. This corn-free period takes place during August and September.

C. Landscaping/Turf

Kikiaola currently uses a dual system for potable and non-potable water at their Plantation Cottages. Potable water is obtained from the County system. Non-potable water is obtained from Waimea River, and used for irrigation of approximately 42 acres of landscaping and turf located makai of Kaumualii Highway and directly west of Waimea Town. The river water is conveyed from Waimea Ditch via an old 8-inch pipe, which is in poor condition, and will most likely have to be replaced in the near future. This 8-inch pipe runs down Waimea Canyon Road and crosses Kaumualii Highway. (This system used to be the main source of water for the mill.) The irrigation water is then dispersed throughout the 42 acres. Water for the irrigation system is also supplemented by water from a well, located on Kikiaola land, just makai of the highway and on the mauka edge of the property. (See Exhibit 2 for location of well.)

VI. DEPARTMENT OF HEALTH REQUIREMENTS

A. Underground Injection of Effluent

The Department of Health (DOH) has been regulating underground injection of effluent in accordance with Hawaii State Administrative Rules. Title 11, Chapter 23, "Underground Injection Control", and Chapter 62, "Wastewater Treatment and Disposal". The former is the more specifically applicable regulation for injection wells. The latter is more generally applicable, as it includes the requirements for the disposal component of a treatment system (e.g., standby capacity for injection wells).

An important aspect of Chapter 23 is the establishment of the Underground Injection Control (UIC) Line. This line delineates the limits mauka of which injection of effluent is not allowed to preserve potential groundwater aquifers. The Waimea WWTP borders this line, but on the mauka side. One of the criterion for establishment of the UIC Line by DOH was that the total dissolved solids (TDS) concentration of the receiving groundwater be at least 5,000 mg/l.

A recent occurrence has been the involvement by the U.S. Environmental Protection Agency (EPA) in issuing underground injection permits. In essence, EPA does not recognize the UIC Line as being the delineation for injection of effluent. Furthermore, EPA's criterion for potential potable groundwater development is that the TDS concentration of the receiving aquifer must be at least 10,000 mg/l.

Based on DOH's regulations and EPA's over-riding criterion, the injection well(s) must be **both** makai of the UIC Line, and the well must be deep enough to inject the effluent into an aquifer with a TDS concentration exceeding 10,000 mg/l.

Chapter 62 requires the following effluent quality for disposal via injection wells:

Five-day biochemical oxygen demand (BOD) shall not exceed 30 mg/i
 (arithmetic average of composite samples);

- Total suspended solids (TSS) shall not exceed 30 mg/l (arithmetic average of composite samples); and
- Chlorine residual shall not be less than 0.1 mg/l (any grab sample).

Past experiences with injection wells, however, indicates that a "rule-of thumb" maximum BOD/TSS concentrations of 5 mg/l is desirable - i.e., a 30 mg/l effluent would probably result in frequent cloggage of the well.

Another qualitative parameter - which is not included in Chapter 62, but expected to be considered in EPA-issued injection well permits - is nutrient concentration of the effluent (i.e., nitrogen and phosphorus). The reason for concern is that subsurface migration of nutrient-rich effluent into coastal waters could result in algal blooms. A study is presently being conducted for the Lahaina Wastewater Reclamation Facility on Maui in regards to this matter. The results of this study are not yet available.

EPA reviewed the June 25, 1993 draft of this report, and concluded that nutrient removal for the Waimea WWTP effluent would not be necessary if certain conditions are met. (See Appendix D for EPA's letter to DOH, Safe Drinking Water Branch.) Their comments are as follows:

- If injection is into an aquifer that has greater than 10,000 mg/l total dissolved solids, then injection is not into an underground source of drinking water (USDW) and drinking water standards do not apply.
- If injection is into a USDW or the injectate migrates into a USDW, then EPA could require the injectate to meet maximum contaminant levels (MCLs).
- Should an injection well be approved and surface water quality problems
 develop, such as algal blooms, EPA may request studies to determine if
 effluent from the injection wells is reaching the ocean. If it is shown that
 effluent is entering the ocean, then the injectate would be subject to
 surface water standards.

Through discussions with DOH, it was verified that the Safe Drinking Water Branch concurs with EPA's findings. If underground injection wells are to be constructed, then permits would be issued by the State, not EPA.

Another regulatory issue is the capacity of the injection well(s), and the need for standby capacity. Chapter 62 requires that the primary injection well and a standby injection well each have the capacity to accommodate the peak flow from the WWTP. (The peak flow can be determined by using the Babbit formula or, DOH may consider the historical flow records as a substitute, provided the records include extreme flow conditions. [See Appendix E.]) This is a definite requirement when the only method of disposal is injection wells. However, it becomes interpretive when the primary method for effluent discharge is reuse, with injection well(s) as a backup. The need for a standby injection well - or for that matter, any injection well at all - becomes even more questionable if the reuse system has an effluent storage component as a backup.

Based on correspondence with DOH's Wastewater Branch (Appendix E), which regulates Chapter 62, it was determined that the following DOH requirements would apply to an injection well(s) as a backup to a DOH-approved reuse system:

- No injection wells are required if the reuse system has a reclaimed water reservoir as a backup. The capacity of such a reservoir must conform to DOH's guidelines for reuse of reclaimed water.
- A single injection well capable of accommodating the peak flow is sufficient as a backup to the reuse system, in lieu of a backup reclaimed water reservoir.

B. Water Reclamation

DOH recently completed their "Guidelines for the Treatment and Use of Reclaimed Water", November 22, 1993. Although these guidelines are not expected to be adopted as Administrative Rules for at least a year-and-a-half, DOH

SUITABLE USES OF RECLAIMED WATER	R1	R2	R3
Parks, elementary schoolyards, athletic fields and landscapes around some residential property	Α	Ü	N
Roadside and median landscapes	Α	U/B	N
Non-edible vegetation in areas with limited public exposure	Α	AB	U
Sod farms	Α	AB	N
Ornamental plants for commercial use	Α	AB	N
Food crops above ground & not contacted by irrigation	Α	ِّ ن	N
Pastures for milking and other animals	Α	U	N
Fodder, fiber and seed crops not eaten by humans	Α	AB	טם
Orchards and vineyards bearing food crops	A	טם:	DU
Orchards and vineyards not bearing food crops during irrigation	Α	АВ	DU
Timber and trees not bearing for crops and timber	Α	AB	DU
Food crops undergoing commercial pathogen destroying process before consumption	Α	AB.	טם
SUPPLY TO IMPOUNDMENTS: (A)llowed (N)ot allowed			
Restricted recreational impoundments	A	N	N
Basins at fish hatcheries	A	N.	N
Landscape impoundments without decorative fountain	A	. A	N
Landscape impoundments with decorative fountain	A	N	N
SUPPLY TO OTHER USES: (A)llowed (N)ot allowed		· · · · · · · · · · · · · · · · · · ·	
Flushing toilets and urinals	A	N	N
Fire fighting	A	N	N
Commercial and public laundries	A	N	N
Cooling saws while cutting pavement	A	. N°	N
Decorative fountains	A	N	N
Washing yards, lots and sidewalks	Α	N	N
Flushing sanitary sewers	Α	Α	N
High pressure water blasting to clean surfaces	Α	N	N
Industrial Process without exposure of workers	Α	A	N

SUITABLE USES OF RECLAIMED WATER	R1	R2	R3
Industrial Process with exposure of workers	Α	N	N
Cooling or air conditioning system without tower, evaporative condenser, spraying, or other features that emit vapor droplets	Α_	Α	N
Cooling or air conditioning system with tower, evaporative condenser, spraying, or other features that emit vapor or droplets	A	N	N
Industrial boiler feed	A	Α	N
Water jetting for consolidation of backfill material around potable water piping during water shortages	A	N	N
Water jetting for consolidation of backfill material around piping for reclaimed water, sewage, storm drainage and gas; and electrical conduits	A	Α	N
Washing aggregate and making concrete	Α	Α	N
Dampening roads and other surfaces for dust control	Α	A	N
Dampening brushes and street surfaces in street sweeping	A	A	N

REFERENCE: Department of Health's "Guidelines for the Treatment and Use of Reclaimed Water", November 22, 1993.

The following precautions apply to R-2 Water:

- Signs shall be posted where reclaimed water is used.
- Adequate measures shall be taken to prevent ponding of reclaimed water.
- Reclaimed water shall always be managed to avoid conditions conducive to proliferation of mosquitoes and other disease vectors, and to avoid creation of a public nuisance or health hazard;
- No discharge, runoff, or overspray shall extend beyond the approved use area boundaries.
- Spray of reclaimed water shall not be allowed to contact an external drinking water fountain.

- R-2 water used in spray irrigation shall be performed during periods beginning when the area is closed to the public and the public is absent from the area, and end a least one hour before the area is open to the public. All subsurface irrigation may be performed any time.
- Spray irrigation of landscape or crops shall be limited so that the outer periphery of the irrigated area is not within 500 feet of:
 - a. A residence or property; or
 - b. A place where public exposure could be similar to that at a park, elementary school yard or athletic field.
- Whether the discharge is from a tank truck, sprinkler, or other device, or whether the discharge is runoff, the application of R-2 water shall be controlled by complying with the following:
 - a. Creation of visible mist is minimized;
 - b. Direct, overspray, or runoff, is confined to the approved use area;
 - Direct, overspray, or runoff does not contact or enter a dwelling, food handling facility, passing vehicle, or a place where the public may be present;
 - d. Direct, overspray, or runoff does not contact a drinking fountain, a table, a chair, bench, barbecue area, a yard at a residence, or an area with frequent human contact;
 - e. Direct, overspray, or runoff shall not be allowed to contact or enter a place where access and exposure to wetted surface, could be similar to that at a park, playground, or school yard.

- There shall be no irrigation within a minimum of 100 feet of any drinking water supply well.
- The outer edge of the impoundment shall be located at least 300 feet from any drinking water supply well.
- Drainage shall be controlled to prevent reclaimed water from coming within 100 feet of a drinking water supply well.

The following requirements for storage impoundment (i.e., reservoir) apply to reclaimed water of all three classifications:

- The following apply where reclaimed water is put in any impoundment used as a restricted recreational impoundment or landscape impoundment:
 - Runoff shall be prevented from entering the storage impoundment unless the impoundment is sized to accept the runoff without discharge, or an NPDES permit has been issued for the discharge;
 - b. There shall be no discharge of reclaimed water to any impoundment with less than two feet of freeboard; and
 - c. To retain is contents, impoundment shall have liners impervious to water;
- The time period of 20 days related to storage is subject to reduction, expansion, or elimination if the project proponent demonstrates to the satisfaction of the DOH that another time period is adequate or that less or no storage is needed. The record should be at least a 30 year period or statistically adjusted to a 30 year period;
- The design of system storage capacity shall be sufficient to assure the retention of the reclaimed water under adverse weather

conditions, harvesting conditions, maintenance of irrigation equipment, or other conditions which preclude reuse. The adverse wet weather conditions shall be based on a 50-year storm recurrence interval using weather data that is available from, or is representative of, the area encompassing the design project; and

The control of public access is left to the discretion of the Owner.
 However, signs shall be posted that are consistent with the Public Education Plan of these guidelines.

All new buried transmission piping in the reclaimed water system, including service lines, valves, and other appurtenances shall both be colored purple, and embossed or be integrally stamped/marked "CAUTION: RECLAIMED WATER—DO NOT DRINK", or be installed with a purple identification tape, or a purple polyethylene wrap. Existing potable or nonpotable water lines that are being converted to reclaimed use shall first be accurately located and tested in coordination with DOH.

The maximum monthly application rate of reclaimed water used to calculate both the volume of the storage reservoir and/or an alternate disposal capacity is to be based on the following parameters:

- Evapotranspiration
- Precipitation
- Percolation

Nitrate and total phosphorus concentration in the percolate is also a factor in determining the maximum application rate. The nitrate concentration in reuse irrigation systems should not exceed 3.0 mg/l, and the total phosphorus concentration should not exceed 1.0 mg/l. The maximum monthly application rate — based on evapotranspiration, precipitation and percolation — should be checked against the nitrogen and phosphorus loading limitations.

A detailed presentation on calculation of the application rate and reservoir capacity is included in Section VIII of this study, where the alternatives are evaluated. However, calculations to determine the estimated nitrogen and phosphorus loadings will not be included in this study, since the type of detail required is better suited to Basis of Design Report, which is not within the scope of this study.

C. NPDES

In 1972, the U.S. Congress passed amendments to the Federal Water Pollution Control Act (referred to as the Clean Water Act) prohibiting the discharge of any pollutant to navigable waters from a point source unless the discharge is authorized by a National Pollutant Discharge Elimination System (NPDES) permit. The NPDES program was traditionally focused primarily on reducing pollutants in discharges of industrial process wastewater and municipal sewage. However, in 1988 the "National Water Quality Inventory" concluded that pollution from diffuse sources, i.e., storm water runoff from agricultural and urban areas, are leading causes of water pollution.

The Clean Water Branch of DOH is responsible for the issuance of NPDES permits. The requirements for NPDES permits are stated in Hawaii Administrative Rules, Title 11, Chapter 55, "Water Pollution Control", which was adopted in October of 1992. There are two categories of NPDES permits — General Permits and Individual Permits. Under DOH's General Permit (GP) Program, six categories of storm water and non-storm discharges are covered.

At the present time, no GPs are required for the Waimea WWTP. One GP which may be required in the future if modifications are made to the lower effluent reservoir, is a GP which covers storm water discharges associated with construction activities. Currently, this GP applies to construction areas of five acres or more. However, there is a strong possibility that the requirements will

become more stringent in the near future and the area may be reduced from five acres to one acre.

Presently, Kekaha utilizes effluent from the Waimea WWTP, which has been mixed with storm water, for sugar cane cultivation. The effluent is conveyed from the lower reservoir to the cane fields via a series of irrigation ditches. Excess effluent and stormwater drains from the fields to the irrigation ditches. This agricultural drainage is then pumped and recycled to other fields. During dry conditions, this effluent/storm water mixture does not enter the ocean. However, during storm conditions, overflow may occur, during which the effluent may enter the ocean. Kekaha has an individual NPDES permit (No. HI0000086) which covers this type of discharge.

In the future, if Kekaha discontinues using the effluent for sugar cane irrigation, then a new NPDES permit would be required since effluent discharges to state waters would no longer be covered under Kekaha's permit. The owner of the system from which a discharge may occur (i.e., overflow from the storage reservoir, or runoff from irrigated fields), most likely, would be the party required to obtain the NPDES permit.

VII. EVALUATION CRITERIA

A. Treatment Efficiency

Pursuant to DOH's Chapter 62 and Water Reclamation Guidelines, the following minimum effluent quality must be achieved for the alternatives being considered (i.e., reuse and/or injection wells):

- Average BOD concentration of 30 mg/l
- Average TSS concentration of 30 mg/l
- Median Fecal coliform value of 4 per 100 ml

Presently, the Waimea WWTP meets these criteria. In fact, the effluent BOD and TSS concentrations are on the order of 3 and 5 mg/l, respectively. (See Table 5.) Also, as stated previously in Section VI, EPA and the State will not require nutrient removal prior to effluent disposal via injection wells.

B. Flow Rates/Volumes

Presently, flow rates at the Waimea WWTP are consistent throughout the year, with a monthly average range of 210,000-270,000 gpd. The median flow rate is 240,000 gpd. (See Table 5.)

Also, peak days recorded over the past three years indicate that a peak day factor of 2.0 is appropriate. This peak day factor is based on DOH's letter, which states that historical flow records may be used as a substitute for the Babbit formula. (See Appendix E.) This conclusion is significant, in that calculation of the peak factor using the Babbit formula — as required by DOH's Chapter 62 — would result in a factor of 4.0. Applying this conclusion to the DOH requirement that the injection well must accommodate the peak flow would result in a two-fold capacity difference.

Another flow-related matter is that expansion of the WWTP beyond its current 300,000 gpd capacity is dependent on development of the Kikiaola Master Plan.

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The 1971 Austin, Smith & Associates, Inc. Preliminary Engineering Study estimated a first phase average flow of 272,000 gpd, and an ultimate flow of 442,000 gpd. The first phase projection was realized, as there are only 72 house lots in Waimea that are yet to hook up to the County system (62 lots are still vacant). Based on 400± gpd per lot, the additional flow from these lots would be 29,000 gpd, resulting in an ultimate flow of about 270,000 gpd.

C. Storage

The existing lower reservoir — which currently receives effluent from the WWTP — is intended to be the ultimate storage reservoir for the reclaimed water. This 8± million gallon reservoir has the capacity to accommodate DOH's "rule-of-thumb" 20-day storage capacity requirement for the current 300,000 gpd flow. It can probably be demonstrated that — because of the generally low-rainfall climatic condition of the study area — less than 20 days of storage would be sufficient, thereby accommodating the 600,000 gpd ultimate flow of this study.

At the present time, lining of the storage reservoir is not required. However, when DOH's reclamation guidelines are signed into law (mid-to-late 1995), all new and existing effluent storage reservoirs will need to be lined. There are two exceptions in which lining the reservoir would not be necessary, they are:

- (1) If the soil of the reservoir has a permeability less than 10⁻⁷ cm/s, then the soil would be considered impervious; and
- (2) Monitoring test results prove that groundwater quality in the surrounding area is not negatively affected.

The inlet and outlet piping would also need to be modified.

D. Irrigation Method

The three methods of irrigation considered were drip, spray and surface (other than spray). DOH's definitions for these three methods — in their water reclamation guidelines — are as follows:

 "Drip irrigation" means application of water from emitters, either on the surface or subsurface that are part of the piping system alongside the plants being irrigated and that discharges at a rate not to exceed 2 gallons per hour per emitter.

Subsurface drip irrigation means application of reclaimed water at least 4 inches below the finished grade, by discharging it from orifices in piping.

- "Spray irrigation" means application of reclaimed water to land to maintain vegetation or support growth of vegetation by spraying it from sprinklers, micro-sprinklers or orifices in piping.
- "Surface irrigation" means application of reclaimed water by means other than spraying such that contact between the edible portion of any food crop and reclaimed water is prevented.

Drip irrigation has the following advantages over the other two irrigation methods:

- Minimal health-related restrictions, in regards to hours of irrigation and setback distances from areas of potential public exposure to the applied water.
- Maximum application volume, due to a high uniformity coefficient i.e., more even distribution across the irrigated area, thereby preventing ponding and runoff.
- Lower pressure requirement at the emitter (less than 20 psi vs. 60+ psi),
 which results in lower power cost and lower capital cost associated with
 lower-pressure transmission lines.

E. Land Issues

The following land issues were considered in evaluating the alternatives:

- The potential irrigation areas are very flat, and conducive for all types of irrigation methods.
- A highly permeable soil below the UIC Line is desirable for maximum infiltration and, hence, maximum volume disposal of the water.
- Development of the Kikiaola Master Plan would not only affect current potential irrigation areas, but possibly also impact the availability of the existing lower reservoir. Based on discussions with Belt Collins & Associates, Kikiaola's consultant for the Master Plan, the existing reservoir may be abandoned and displaced with housing.

F. Cost

Construction and operation/maintenance costs are usually the primary considerations in evaluating alternatives. The expected accuracy of most of the construction costs presented in the subsequent sections of this study — being preliminary — is on the order of 30%±. Therefore, although the methodology used is appropriate for comparing the alternatives at this planning stage, these costs should not be interpreted as being probable costs for any one alternative. Extensive field work would have to be conducted to more precisely estimate the construction cost.

G. Schedule

The pending expiration of agreements between Kikiaola and the County and Kekaha is the primary motive for expediting the implementation of an effluent reuse/disposal program. Both of the primary alternatives being considered — i.e., irrigation reuse and disposal via injection wells — would require well over a year to obtain approval from DOH and to construct. Based on past experience —

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albeit minimal, due to limited precedence – in establishing a reuse program in Hawaii, the injection well alternative may take less time to implement.

H. Injection Well Constraints

DOH- and EPA-imposed constraints on injection wells primarily relate to the TDS concentration of the receiving aquifer being greater than 10,000 mg/l. Mink & Yuen, Inc. evaluated the alternative of injection wells and recommended that such wells be constructed along Kaumualii Highway, or between the highway and the coast. (See Appendix A for Mink & Yuen's report.)

VIII. DESCRIPTION OF ALTERNATIVES

A. Renegotiation of Kiklaola/County Agreement

The agreement between Kikiaola and the County for discharge of effluent from the Waimea WWTP to Kikiaola's irrigation reservoir expires on December 31, 1994. Renegotiation is primarily dependent on implementation of Kikiaola's Master Plan, especially in regards to abandonment of the lower reservoir.

Another factor related to continuance of the Kikiaola/County agreement is extension of Kikiaola's lease agreement with Kekaha for cultivation of sugar cane by Kekaha, which expires on December 31, 1993.

Kikiaola has been very cooperative in providing information pertinent to this study, and appears receptive to establishment of a water reclamation program — other than the current arrangement — if cane cultivation on Kikiaola land is discontinued. However, based on implementation of their Master Plan, it appears unlikely that the Kikiaola/County agreement will be extended as-is — or at least, not on a long-term basis. Therefore, it would be prudent for the County to not depend on continuance of the current effluent disposal method — i.e., discharge into Kikiaola's reservoirs — and to, instead, be actively involved in the ultimate usage of the effluent. Even if the current arrangement could be extended on a long-term basis, it is likely that when DOH's water reclamation guidelines are adopted as Administrative Rules, a compliance schedule may be imposed by DOH. Consequently, capital outlay by the County to upgrade the irrigation system to DOH requirements (e.g., lining of the storage reservoir) would probably be postponed, rather than totally avoided.

B. Underground Injection

Disposal of 1.2 million gallons per day (mgd) of effluent via injection wells was evaluated by Mink & Yuen, Inc. (See Appendix A.) This flow rate is consistent with the suggested future peak flow rate when the WWTP treatment

capacity is expanded to 0.60 mgd. The 2.0 peak factor - vs. 4.0 if the Babbit formula is used - has been documented by past flow records for the WWTP.

Mink recommends that injection wells be constructed along Kaumualii Highway, or between the highway and the coast. Therefore, it is proposed that the wells be constructed within the County-owned site for Wastewater Pump Station (WWPS) 'A'. (See Exhibit 9 for proposed layout.) The effluent line from the WWTP to the wells would parallel the wastewater force main from WWPS 'A' to the WWTP, thereby remaining within the County's existing 30-foot wide easement.

As recommended by Mink, the wells would have to be 600± feet deep. The top 400± feet would have a 14-inch diameter solid casing, grouted into the caprock. The bottom 200 feet would have a 14-inch diameter screened casing for discharge of the injected effluent into the aquifer — which, at that depth, is expected to have a TDS concentration of at least 13,000 mg/l, and more likely 22,000 mg/l.

The option of phasing the wells to handle the current peak flow of 600,000 gpd, with future wells to handle the future peak flow, was considered. However, there is very little cost difference between a 600,000 gpd well and a 1.2 mgd well. This is based on the fact that the only difference between a 1.2 mgd well and a 600,000 gpd well would be that the open hole may need to be deeper to accommodate a flow of 1.2 mgd. Therefore, it was determined that if injection wells are pursued, then each well should have a capacity of 1.2 mgd to handle the peak flow rate for the future capacity of the WWTP.

Nutrients and other dissolved matter in the effluent will eventually dissipate into the sedimentary caprock, and then ultimately discharge into the sea at a considerable distance from the coast, and at a depth of hundreds of feet. The injected effluent will be prevented from mixing in coastal waters by the thick wedge of caprock.

The number, and discharge capacity, of injection wells is contingent upon implementation of a reuse system. The following scenarios are possible:

- No reclamation system. At least two injection wells, each with a capacity of 1.2 mgd.
- Reclamation system without a backup reservoir. At least one injection well with a capacity of 1.2 mgd.
- Reclamation system with a backup reservoir. No injection wells necessary.

Effluent quality criteria for the injection well alternative relates to the BOD, TSS and chlorine residual concentrations. The current performance of the WWTP is such that the concentrations of these three parameters are well within the limitations established by DOH (e.g., less than 10 mg/l BOD/TSS vs. DOH's maximum of 30 mg/l). As mentioned previously in Section VI of this report, EPA will not require nutrient removal if the conditions set forth in their letter are met. (See Appendix D.)

The estimated construction cost for each injection well is \$350,000. (See Table 8 for itemization.) The estimated cost for the effluent transmission line from the WWTP to the wells, including appurtenances, is \$60,000 (800 L.F. @ \$60/L.F. + \$5,000 misc. + 10% contingency).

TABLE 8. ESTIMATED CONSTRUCTION COST FOR INJECTION WELL

83			000013171-000	1 25.6688 Z8008 C808 C
ITEM NO.	EST'D. QTY.	DESCRIPTION	UNIT PRICE	TOTAL
1.	L.S.	Mobilization, including transport to and from, of all necessary materials and equipment to conduct all well drilling operations at the site and testing.		
		Lump Sum		\$20,000
2.	600	Lin. Ft. of Well Drilling to permit the complete installation of well casing.		
		Per Lin. Ft.	\$350.00	\$210,000
3.	400	Lin. Ft. of 14-inch i.D., minimum 5/16-inch thick solid steel casing, furnished and installed, in place complete.		
		Per Lin. Ft.	\$65.00	\$26,000
4.	200	Lin. Ft. of 14-inch I.D., minimum 5/16-inch thick perforated or louvered screen steel casing, furnished and installed, in place complete.		
		Per Lin. Ft.	\$75.00	\$15,000
5.	400	Lin. Ft. cement grouting of annular space around solid casing.		
		Per Lin. Ft.	\$35.00	14,000
6.	L.S.	Pump and injection testing of well capacity.		
		Lump Sum		\$25,000
7.	L.S.	Demobilization, including removal of all materials and equipment from the site, clean-up operations and restoration of any existing improvements.		
		Lump Sum		\$10,000
		S 10% CONT	UBTOTAL INGENCY	\$320,000 32,000
			TOTAL	\$352,000
			SAY	\$350,000

Based on these component costs, the total estimated construction costs for the first two scenarios – at an average flow of 0.60 mgd – would be as follows:

No Reclamation System

	Two Injection Wells @ \$350,000 each Effluent Transmission Line	= =	\$ 700,000 <u>60.000</u>
		Total	\$ <u>760.000</u>
•	Reclamation System without Backup Reservoir		
	One Injection Well Effluent Transmission Line	=	\$ 350,000 <u>60,000</u>
		Total	\$ <u>410,000</u> *

^{*}Injection well related costs. Reclamation system costs must be added to derive total system cost.

C. Reciamation

Reclamation which occurs above the UIC Line is subject to strict application, monitoring and reporting requirements. Therefore, the reuse alternatives considered in this report were restricted to areas below the UIC Line. This does not mean that reclamation above the UIC Line is not allowed, however, irrigation above the line would be much more costly and labor intensive.

Irrigation reuse with 300,000 gpd and 600,000 gpd of R-2 water was evaluated for the following basic alternatives:

- <u>Sugar cane</u>. This alternative assumes renewal of the lease agreement between Kikiaola and Kekaha, and applies only to 140 ± acres mauka of Kaumualii Highway. (See Exhibit 10 for the proposed irrigation reuse areas.)
- <u>Seed corn.</u> This alternative depends on lease agreements between Kikiaola and seed corn growers (i.e., DeKalb Plant Genetics or Pioneer

HiBred International, Inc.) and applies only to 140 \pm acres mauka of the highway.

- <u>Pasture</u>. This alternative applies to 140 ± acres mauka and 100 ± acres makai of the highway.
- Landscaping/turf. This alternative currently applies to 12 ± acres makai
 of the highway at Waimea Park. Waimea High School and the Veterans
 Hospital were also considered for irrigation reuse, but were decided
 unsatisfactory. Further discussion on irrigation reuse at the School and
 Hospital is presented later in this section.

In the future, this alternative would apply to the golf course in Kikiaola's Master Plan. However, as indicated previously in this study, implementation of the Kikiaola Master Plan will require a supplemental study on further expansion of not only the treatment capacity of the WWTP, but also of the effluent reuse/disposal system. Furthermore, DOH's water reclamation guidelines incorporate special considerations for golf course irrigation. Therefore, evaluation of golf course irrigation with reclaimed water has not been included in this study.

Four different combinations of these effluent reuse alternatives were considered viable. The first three scenarios would involve irrigation of sugar cane, seed corn or pasture mauka of the highway, and pasture below the highway. Due to the high percolation rate of the sandy soil below the highway, this area can be "over-irrigated" if the crops mauka of the highway cannot use the entire flow from the WWTP. Therefore, pasture is a good crop for the area makai of the highway because it is able to accept large amounts of water without damaging the vegetation.

The fourth scenario would involve irrigation of turf/landscaping at Waimea Park only, without any irrigation makai of the highway. The advantage of this scenario is that it does not involve lease negotiations with Kikiaola or any crop growers.

Another alternative considered was cultivation of seed corn makai of the highway, in lieu of pasture. Seed corn can be over-irrigated without causing damage to the crop. However, disadvantages of seed corn cultivation below the highway include: (1) the need for lease negotiations between Kikiaola and seed corn growers; (2) a two month fallow period during August and September when the corn would not be irrigated; and (3) the seed corn may require more water than what is available from the WWTP, even after expansion of the plant. For these reasons, water balance tables were not developed for scenarios involving seed corn cultivation makai of the highway.

A summary of the four scenarios considered follows:

Scenario 1: Sugar cane cultivation mauka of the highway and pasture makai of the highway.

Scenario 2: Seed corn cultivation mauka of the highway and pasture makai of the highway.

Scenario 3: Pasture both mauka and makai of the highway.

Scenario 4: Turf mauka of the highway at Waimea Park and no reuse makai of the highway.

Water balance tables (Tables 9-16) were developed for each scenario to determine the design application rate of the reclaimed water and the required storage volume for the current flow rate of 300,000 gpd and a future flow rate of 600,000 gpd.

The data in the water balance tables were determined in accordance with DOH's "Guidelines for the Treatment and Use of Reclaimed Water". The maximum monthly application rate of reclaimed water is based on evapotranspiration, precipitation and percolation (or permeability). The tables were developed to obtain approximate application rates, and thus, nutrient loadings were not taken into consideration. Determination of maximum nutrient

loadings would be calculated for a Basis of Design Report, which is not in the scope of this study.

Since all proposed reclamation areas are below the UIC Line, percolation of the effluent into the soil would be allowed. However, for comparison purposes, the application rate and the storage volume were calculated with percolation and without percolation, hence, the two sub-tables within each table.

TABLE 9. WATER BALANCE FOR SCENARIO 1

CURRENT FLOW RATE = 300,000 GPD SUGAR CANE MAUKA OF HIGHWAY PASTURE MAKAI OF HIGHWAY

WITH PERCOLATION

	(10) (11) (15) (14) (15)	MMAV Total Use Flow Surplus Cumulative Storage Makai (240 acres) 0.3 MGD Deficit sur/def Volume (100 ac) (MG) (MG) (MG) (MG)	511.46 502.16 -502.16 -502.16 0.00 488.08 472.85 8.40 -464.45 -968.61 0.00 521.44 530.16 9.30 -520.86 -1487.47 0.00 508.86 522.48 9.00 -513.48 -2000.95 0.00 527.68 544.11 9.30 -523.81 -2535.77 0.00 513.29 532.30 9.00 -523.30 -3059.06 0.00 529.74 540.21 -3599.86 0.00 -539.12 -4139.09 0.00 529.74 9.00 -518.47 -4657.56 0.00 521.89 531.70 9.30 -522.40 -5179.96 0.00 521.87 507.46 9.30 -522.40 -5179.96 0.00 511.57 511.57 9.30 -502.27 -518.62 0.00	6157.15 6290.19 109.50 -6180.69
	<u>(6)</u>	MMAV M Mauka M (140 ac) (10 (MG) (10	0 - 8 0 4 0 - 8 0 - 8 8	133.04 6
	(8)	MMAR Makai (inches)	188.31 197.34 197.36 194.29 188.39 185.04 188.15 192.15 184.69	2266.99
WILL FEACOLATION	ω	MMAR Mauka (inches)	0.00 1.28 2.29 3.58 4.32 5.00 5.18 4.91 4.33 2.58 1.54	34.99
S	(9)	DMPR Makei (Inches)	187.49 169.34 181.44 187.49 187.49 187.49 187.49 181.44 181.44	2207.52
	(3)	DMPR Mauka (inches)	88 88 88 88 88 88 88 88 88 88 88 88 88	0.00
	(4)	ET Makai (inches)	4.99 5.48 6.94 7.74 7.78 8.02 8.35 8.31 7.50 6.56 5.38	81.20
	69	ET Mauke (inches)	3.41 3.74 4.73 5.00 5.30 5.47 5.65 5.65 5.65 3.67 3.67	55.37
	(2)	Precip. at Kekaha (inches)	2.48 2.48 2.44 1.42 0.98 0.61 0.75 0.75 2.13 3.70	21.77
	ε	Pan Evap. at Kokaha (Inches)	4.54 4.98 6.51 6.51 7.09 7.09 7.09 7.09 7.09 7.09 7.09 7.09	73.53
		Month	MASS APS AUG AUG SEP OCT	ANNITAL

WITHOUT PERCOLATION

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(45)		Storage	(MG)	14.01	9.50	8	0.0	800	000	2	3 3	8.0	8.0	8.0	20	3 6	0.82		
(14)	<u>.</u>	Cumulative sur/def	(MG)	7.06	2.55	60:6-	-29.79	-55.38	45.89	1	3	-147.48	-173.16	-186.34	10001	10101	00.081		
(13)	<u></u>	Surplus Deficit	(MG)	2.06	4.51	-11.64	-20.69	25.60	30.51		07:15	8.82 8.80	-25.68	-13.18	7.5	5 6	6.85	-185.06	
55	(15)	Flow 0.3 MGD	(MG)	930	8.40	9.30	9.00	5	8	3 6	9.30	06.9 0.30	9:00	08.6	5	3 3	9:30	109.50	
(3)	==	Total Use (240 acres)	(MG)	2.24	12.91	20.94	89.68	24.00	20.64	10,50	41.00	39.20	34.68	22.48	1 3	70.4	2.35	294.56	
1017	<u> </u>	MMAV	(100 ac) (MG)	224	8.14	12.22	16.07	10.45	2 2	3	21.29	20.52	18.23	12 67		72.8	2.35	161.53	
19	<u> </u>	MMAV Mauka	(140 ac) (MG)	80	4.77	A 72	13.62	16.44	5 5	19.00	19.71	18.68	16.45	180		200	0.00	133.04	
	<u> </u>	MMAR	(Inches)	0.82	90	2 2	3 6	100	8 1	3	7.84	7.56	6.71	ART	ì	8	0.87	59.47	
 - -	E	MMAR	(inches)	٤	- 6	2 8	97.5	3 5	26.4	2.00	5.18	4.91	433	200	00.3	<u> </u>	0.00	34.99	
	<u> </u>	DMPR	(inches)	5	8 8	3 8	3 8	3 6	300	8.0	000	000	8	3 8	3	0.0	0.00	000	
	<u>.</u>	DMPR	(inches)	8	88	8.8	38	3	8.0	8.0	0000	800	8 8	88	3.0	0.0	00:0	0.0	
	Ð	Metal	(inches)	8	7 Y	5. C.	4 6	¥.	7.78	8.02	8.35	B 25	1 6	00.7	6.26	5.38	4.57	81.20	
	ල	L LL	(Inches)	,,,	4.0	3.74	4.73	200	5.30	5.47	5	22.1	3 5	5.12	4.47	3.67	3.11	55.37	
ļ	(2)	Precip.	(inches)		7. 9	2.48	2.44	1.42	0.98	0.47	140	1	2 5	67.0	8.	2.13	3.70	21.77	
İ	ε	Pan Evap.	at Kekana (inches)		¥.	4.98	6.31	6.67	20.7	7.23	9		8	6,82	2.96	8	4.15	73.53	3
		Month			= {	FEB	MAH	APR	MAY	2	3 =	1	AUG	SEP	ঠ	200	250	ANNITAL	WINDY.

TABLE 10. WATER BALANCE FOR SCENARIO 1

FUTURE FLOW RATE = 600,000 GPD SUGAR CANE MAUKA OF HIGHWAY TURF MAKAI OF HIGHWAY

WITH PERCOLATION

					1	Į	107	3	100	(11)	125	3	(14)	(15)
	(2)	ව	€	(S)	9	S	<u>.</u>	<u> </u>	<u> </u>	=	(16)		· · ·	
	Precio.	ш	تتا	DMPR	DMPR	MMAR	MMAR	MMAV	MMAV	Total Use	Flow	Surplus	Cumulative	Storage
-	at Kekaha	Mauka	Makai	Mauka	Makai	Mauka	Makai	Mauka	Makei	(240 acres)	0.3 MGD		sur/der	AUDIOA
(inches)	(uches)	(inches)	(inches)	(inches)	(inches)	(Inches)	(inches)	(140 ac)	(100 ac)	(WG)	(WG)		(MG)	(MG)
								(mid))					188
1	14	2.41	00 7	000	187.49	0.00	188.31	0.00	511.46	511.46	# 8.60	492.86	492.86	800
,	7	74.0	ay u	2	169.34	1.26	172.34	4.77	468.08	472.85	16.80	456.05	-948.91	8.0
8	2.40	7	2 2	3 8	107.40	0000	101 00	R 72	521.44	530.16	18.60	-511.56	-1460.47	8.0
<u>بر</u>	2.44	5.73	5.0	300	51.101		407.00	5 6	508 BG	522 AB	18.00	-504 48	1964.95	00:0
6	1.42	200	7.34 4.34	800	181.44	00.5	8.0	20.01	3 1		900	100	240047	8
6	8	5.30	7.78	00:00	187.49	4.32	194.28	16.44	527.68	244.11	20.50	-525.51	74:00:47	3 6
į 8	240	2 47	208	000	181.44	5.00	188.99	19.00	513.29	532.30	18.00	-514.30	-3004.76	0.00
Ş	7 0	F 6	100	2 2	187.40	8 8	195.33	19.71	530.51	550.21	18.60	531.61	-3536.38	0.0
.53	0.51	5.03	0.50	3	101.13	2 3	200		27.00.74	E40 42	19.63	.520 R2	4066 19	000
55	0.75	5.66	8.31	000	187.49	4.91	5	8	77.7	70.75	3 5	1000	-	8
60	0,70	5 12	7.50	000	181.44	4.33	188.15	16.45	511.02	527.47	18.00	÷.605	45/5.00	3 3
9 6		1 4 4 7	8 8	5	187.49	2.58	192.15	9.81	521.89	531.70	18.60	-513.10	-5088.76	0.00
5	8		3	3 3	2 3		200	10 1	501 63	En7 46	18.00	489 46	-5578.22	00:0
4.89	2.13	3.67	5.38	0.00	181.44	<u>\$</u>	60.40	3	30.15	21.13	3 5		20.45	2
4.15	3.70	3.11	4.57	0.00	187.49	800	188.35	0.00	511.57	511.57	18.60	-492.97	-9071.19	8.0
73.53	21.77	55.37	81.20	00:0	2207.52	34.99	5266.99	133.04	6157.15	6290.19	219.00	-6071.19		

WITHOUT PERCOLATION

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(35)	Storage Volume (MG)	35.94	रें रे	37.	ĸ	<u></u>	<u></u>	<u></u>	<u></u>	ď		i ·	m	19	
(14)	Cumulative sur/def (MG)	16.36	27.52	17.91	6.21	-10.08	-31.59	-53.99	-74.58	25.25	3	1.00	-91.81	-75.56	
(13)	Surplus Deficit (MG)	16.36	3.83	-2.34	-11.69	-16.30	-21,51	22.49	20.60	18 68	3 5	8	3.33	16.25	-75.56
(12)	Flow 0.3 MGD (MG)	18.60	16.80	18.60	18.00	18.60	18.00	18.60	6.85	20.00	3 9	18.50	18.00	18.60	219.00
(11)	Total Use (240 acres) (MG)	2.24	12.91	20.94	29.69	34.90	39.51	41.00	8	24.69	3 5	22.48	14.67	2.35	294.56
(01)	MMAV Makai (100 ac) (MG)	2.24	8.14	12.22	16.07	18.46	20.50	21.20	22.52	\$ 33	3	12.67	8.82	2.35	161.53
(6)	MMAV Mauka (140 ac) (MG)	0.00	4.77	8.72	13.62	16.44	19,00	19.71	18.68	46.45	2.0	9.81	5.85	0.00	133.04
(9)	MMAR Makai (inches)	0.82	3.00	4.50	5,92	6.80	7.55	7.84	5 5	3	0.0	4.67	3,25	0.87	59.47
(2)	MMAR Mauka (inches)	0.0	1.26	2.29	3.58	4.32	200	41.4	2 6		S	2.58	1.54	0.00	34.99
(9)	DMPR Makai (inches)	0.0	0.00	0.00	000	000	0	8 8	3 8	3 6	8.9	000	000	00.0	0.00
(2)	OMPR Mauka (inches)	0.00	000	000	000	000	86	3 8	3 6	3 5	000	800	5	8	0.00
(4)	ET Makai (inches)	4.99	5.48	6.94	7.34	7.78	200	30.0		5.31	7.50	6.56	4 28	4.57	81.20
69	ET Mauka (inches)	3,41	3.74	473	20.5	200	0.30	6 1	5.69	2000	5.12	4.47	28.7	3.11	55.37
(2)	Precip. at Kekaha (inches)	4.17	2.4B	2.44	1.49	9000	0.30	7.0	0.51	0.75	0.79	1 80	\$	3.70	21.77
ε	Pan Evap. at Kekaha (inches)	4.54	4 08	6.21	6.57	0.01	7.07	R.	7.59	7.55	6.82	202	200	4.15	73.53
	Month	NAL		2 9	500	2	W.A.	NO.	ا ا	AUG	GES	٤	3 3	2 2	ANNUAL

TABLE 11. WATER BALANCE FOR SCENARIO 2

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CURRENT FLOW RATE = 300,000 GPD SEED CORN MAUKA OF HIGHWAY PASTURE MAKAI OF HIGHWAY

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	(12)		Storage Volume (MG)	800 800 800 800 800 800 800 800 800 800	
	(14)		Cumulative sur/def (MG)	-502.16 -963.77 -1481.03 -1990.71 -2521.49 -3040.63 -3577.21 -4097.65 -4599.67 -5118.67 -5614.34	
	(13)		Surplus Deficit (MG)	502.16 461.61 517.26 509.68 530.78 519.14 536.59 520.44 502.02 519.00 495.67	4
	(12)		Flow 0.3 MGD (MG)	9.30 9.30 9.30 9.30 9.30 9.30	16.50
WITH PERCOLATION	(33)	<u> </u>	Total Use (240 acres) (MG)	511.46 470.01 526.56 518.68 540.08 523.14 545.89 523.74 511.67 504.67	6226.11
	(40)	2	MMAV Makai (100 ac) (MG)		6157.15
	ı	<u> </u>	MMAV Mauka (140 ac) (MG)		96.89
		9	MMAR Makai (inches)	188.31 172.34 191.99 187.36 198.99 195.04 188.15 192.15 184.69	2266.99
וידים מבפר		8	MMAR Mauke (inches)	0.00 0.51 1.35 3.26 3.30 4.04 0.00 0.00 0.00 0.00 0.00	18.14
3	1	<u> </u>	DMPR Makal (inches)	167.49 169.34 187.49 181.44 187.49 187.49 187.49 187.49 187.49	2207.52
		<u>.</u>	DMPR Mauka (inches)	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	0.00
		€	ET Makai (inches)	5.48 6.94 7.34 7.78 8.02 8.35 8.31 7.50 6.56 5.38 4.57	81.20
		ල	ET Mauka (inches)	2.72 2.99 3.79 4.00 4.24 4.37 4.55 0.00 0.00 0.00 3.58 2.93 2.93	35.67
		(2)	Precip. at Kekaha (inches)	2.48 2.48 2.44 1.42 0.98 0.51 0.75 0.75 3.70	21.77
		Ξ	Pan Evap. at Kekaha (inches)	4.54 4.98 6.31 6.67 7.07 7.28 7.59 6.82 6.82 6.82 4.89	73.53
			Month	JAN MAR MAY MAY JUL JUL AUG SEP OCT	ANNUAL
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_	_	88.5	14.01 12.34 4.30 0.00 0.00 0.00 0.00 0.00 0.00 0	7
(15)		Storage Volume (MG)		-
(14)		Cumulative sur/def (MG)	7.06 5.39 2.65 1.954 41.11 67.46 94.82 106.04 115.27 125.06	
163)	2	Surplus Deficit (MG)	7.06 -1.67 -8.04 -16.89 -21.58 -26.35 -27.37 -11.22 -9.23 -9.78 -2.89 -2.89 -2.89 -2.89 -2.89	25.023
(5)	(12)	Flow 0.3 MGD (MG)		C.501
	Ξ	Total Use (240 acres) (MG)	224 10.07 17.34 25.88 30.86 35.35 36.67 20.52 18.23 19.08 11.88	230.49
	6	MMAV Makai (100 ac) (MG)	·	161.53
	6	MMAV Mauka (140 ac) (MG)		98.89
	<u>@</u>	MMAR Makai (inches)		59.47
	Ê	MMAR Mauka (inches)	0.00 0.51 1.35 2.58 3.26 3.26 4.04 0.00 0.00 0.00 0.00	18.14
	(9)	OMPR Makai (inches)	000 000 000 000 000 000 000 000 000 00	0.00
	(2)	DMPR Mauka (inches)	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	00'0
	(4)	ET Makai (inches)	4.99 5.48 6.94 7.34 7.78 8.02 8.35 8.31 7.50 6.56 6.56	81.20
	(3)	ET Mauka (inches)	2.72 2.99 3.79 4.00 4.24 4.37 4.55 0.00 0.00 3.58 2.93 2.49	35.67
	(2)	Precip. at Kekaha (inches)	2.48 2.44 2.44 1.42 0.98 0.97 0.75 0.75 1.89 1.89	21.77
	3	Pan Evap. at Kekaha (inches)	4.54 4.98 6.31 6.67 7.07 7.29 7.59 7.55 6.82 6.82 4.89 4.15	73.53
		Month	JAN FEB MAR APR JUL JUL AUG SEP OOT	ANNUAL

TABLE 12. WATER BALANCE FOR SCENARIO 2.

FUTURE FLOW RATE = 600,000 GPD SEED CORN MAUKA OF HIGHWAY TURF MAKAI OF HIGHWAY

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	(15)	č	Volume (MG)	800 800 800 800 800 800 800 800 800 800	
	(14)	•	cumulative sur/def (MG)	492.66 948.07 -1454.03 -1954.71 -2986.33 -3513.61 -4024.75 -4517.77 -5027.47 -5007.11	
	(53)		Surplus Deficit (MG)	492.88 453.21 507.86 500.68 521.48 510.14 527.29 511.14 493.02 509.70 486.67 492.97	
	(12)]	Flow 0.3 MGD (MG)	18.60 18.60 18.60 18.60 18.60 18.60 18.60 18.60 18.60 18.60 18.60 18.60	
	(11)	_	Total Use (240 acres) (MG)	511.46 470.01 526.56 518.88 540.08 528.14 545.89 528.30 528.30 504.67 511.57	
WITH PERCOLATION	(40)		MMAV Makal (100 ac) (MG)	511.46 468.08 521.44 508.86 537.68 513.29 520.51 521.02 521.89 501.62 511.77	
	1	<u> </u>	MMAV Mauka (140 ac) (MG)	0.00 1.93 5.12 9.82 12.40 14.84 15.38 0.00 0.00 0.00 0.00	
	9	<u> </u>	MMAR Makai (inches)	188.31 172.34 191.99 197.36 198.99 195.33 195.04 198.15 198.15 198.15	NO ET 100 CE
IITH PERC	1	<u> </u>	MMAR Mauka (inches)	0.00 0.51 1.35 2.58 3.26 3.90 4.04 0.00 0.00 0.00 0.00 0.00 0.00	
5	1	<u> </u>	DMPR Makai (inches)	187.49 169.34 187.49 181.44 187.49 187.49 187.49 187.49 187.49 187.49 187.49	
		<u>(0</u>	DMPR Mauka (inches)	800 800 800 800 800 800 800 800 800 800	
		Đ	ET Makai (inches)	6.94 6.94 7.34 7.34 7.78 8.02 8.35 8.31 7.50 6.56 6.56 8.37 7.50	
		ල	ET Mauka (Inches)	2.72 2.99 3.79 4.00 4.24 4.37 4.37 4.55 0.00 0.00 0.00 2.93 2.49 3.567	
		(%)	Precip. at Kekaha (inches)	2.48 2.44 1.42 0.98 0.47 0.75 0.79 1.89 2.13 3.70	
		(1)	Pan Evap. at Kekaha (inches)	4.54 4.88 6.69 7.00 7.00 7.00 7.00 7.00 6.82 6.82 6.82 6.82 6.82 6.82 6.82 6.82	30
	,		Month	JAN FEB MAR APR JUN JUL AUG SEP OCT NOV DEC	ANNOW

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(9) (10) (11) (12) (13) (14 MMAV Total Use Flow Surplus Cumul Makai (240 acres) 0.3 MGD Deficit surf (40 ac) (100 ac) (MG) (MG) (MG) 1.03 (100 ac) (MG) (MG) (MG) 1.03 8.14 10.07 16.80 6.73 5.12 12.22 17.34 18.60 -12.26 12.40 18.46 30.86 18.60 -12.26 14.84 20.50 35.35 18.00 -1.32 15.38 21.29 36.67 18.60 -1.32 16.39 -1.32 16.30 -1.22 16.30 -1.32 16.30 -1.32 16.30 -1.32 16.31 18.50 -1.32 16.32 18.50 -1.32 16.33 18.50 -1.32 16.34 18.50 -1.32 16.35 18.50 -1.32 16.36 18.50 -1.32	ส์	
(9) (10) (11) (12) (13 MMAV Total Use Flow Sury Wauka Makai (240 acres) 0.3 MGD Del (40 ac) (100 ac) (MG) (MG) (MG) (MG) (MG) (MG) (MG) (MG) (MG) (MG) (MG) (MG) (100 ac) (MG) (MG) (MG) (MG) (MG) (MG) (11) (12.24 18.60 5.12 12.22 17.34 18.60 12.40 18.46 30.86 18.60 12.40 18.46 30.86 18.60 15.38 21.29 36.57 18.60 15.38 21.29 36.57 18.60 16.40 18.23 18.00 16.50 35.35 18.00 16.50 36.51 18.60 16.50 36.52 18.60 16.50 36.51 18.60	-11.49	
(9) (10) (11) (11) (11) (11) (11) (11) (11	16.25	-11.49
(9) (10) (11 (14 (16) (16) (16) (17) (17) (17) (17) (17) (17) (17) (17	18.60	219.00
(9) (1) (10) (10) (10) (10) (10) (10) (10)	2,35	230.49
_ & 촛불운동	2.35	161.53
MAH Hes) 3.00 2.82 2.55 2.592 6.80 77.55 4.57 4.67 4.67 4.67	3.06	68.96
(8) MMAR Makal (Inches) 3.00 3.00 4.55 5.92 7.78 7.58 7.66 4.66	3.25	59.47
(inches) Mauka (inches) 0000 0000 0.51 0000 0000 0000 0000 000	8 8	18.14
(6) (Aakal (Inches) (100 0.00 0.00 0.00 0.00 0.00 0.00 0.00	8.6	0:00
(5) DMPR Mauka (inches) 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.	8.00	0.00
(4) ET Makal (Inches) 4.99 5.48 6.94 7.34 7.34 7.78 8.02 8.35 8.35 6.56	5.38	81.20
(3) ET Mauka (Inches) 2.72 2.99 3.79 4.00 4.24 4.37 4.55 0.00	2.93	35.67
(2) Precip. at Kekaha (inches) 2.48 2.44 2.44 2.44 0.98 0.98	2.13	21.77
(1) Pan Evap. at Kekaha (Inches) (nches) 6.31 6.67 7.07 7.29 7.59 7.55	8.4	73.53
Month JAN FEB MARY APR JUL JUL SEP SEP	30	ANNUAL

TABLE 13. WATER BALANCE FOR SCENARIO 3

CURRENT FLOW RATE = 300,000 GPD PASTURE MAUKA AND MAKAI OF HIGHWAY

WITH PERCOLATION

	82.	8 8	3 8	3 8	3 :	8	8	8	8	8	<u></u>	8	ğ	\neg
(15)	Storage Volume (MG)			_			_	_					_	_
(14)	Cumulative sur/def (MG)	-505.29	1001R-	20001-	-2027.89	-2572.21	-3105.21	3656.22	4205.39	4732.93	5263.28	-5768.23	-6273.79	
(13)	Surplus Deficit (MG)	-505.29	47.08	92.20	-522.36	544.22	-533.00	-551.02	-549.16	-527.54	-530.33	-504.97	-505.56	-6273.79
(12)	Flow 0.3 MGD (MG)	9.30	2 1	9.30	9.00	8.30	9.00	9.30	9.30	9.00	9.30	00.6	9.30	109.50
(11)	Total Use (240 acres) (MG)	514.59	479.48	538.56	531.36	553.52	542.00	560.32	558.46	536.54	539.63	513.97	514.88	6383.29
(01)	MMAV Makai (100 ac) (MG)	511.46	468.08	521.44	508.86	527.68	513.29	530.51	529.74	511.02	521.89	501.62	511.57	6157.15
(6)	MMAV Meuka (140 ec) (MG)	3.13	11.40	17.11	22.50	25.84	28.70	29.81	28.73	25.52	17.74	12.35	323	226.14
(8)	MMAR Makai (inches)					_		_	_	_			188.35	2266.99
Θ	MMAR Mauka (inches)	0.82	3.00	4.50	5.92	6.80	7.55	7.84	55.4	6.71	4.67	20.6	0.87	59.47
(9)	DMPR Makei (inches)	187.49	169.34	187.49	181.44	187.49	181 44	187.49	187.40	181 44	197.40	181 44	187.49	2207.52
(2)	DMPR Mauka (Inches)	0.0	0.0	0.00	00'0	000	8	8 8	38	8 8	3 8	3 8	8 8	0.00
(4)	ET Makai (inches)	4.99	5.48	6.94	7.34	7.78	200	200	3 6	120	3.0	000	4.57	81.20
(£)	ET Mauka (inches)	4.99	5.48	6.94	7.34	7.78	2	20.0	200	9 6	3 5	0.00	8.57	81.20
(2)	Precip. at Kekaha (Inches)	4.17	2.48	2.44	1.42	800	8 5	7 0	0.0	0.73	8.0	28.	3.70	21.77
ε	Pan Evap. at Kekaha (inches)	4.54	4.98	631	8 87	100	9 6	8	33 1	8.5	20.00	5.96	4.89	73.53
	Month	NA	E	MAN	100	2 2	¥ .	200	7	AUG	SEP	5) i	ANNUAL

WITHOUT PERCOLATION

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(15)	Storage	9	(min)	7.59	8	8.0	0.00	8	8	900	0.0	0.00	0.0	0.00	3.66		
£	Cumulative	200	(mag)	3.93	-7.21	-27.25	-56.82	-91.83	-132.03	-173.83	-213.78	-248.53	-269.65	-281.82	-278.16		
(1 3	Surplus	3	(MG)	3.83	-11.14	-20.04	-29.57	-35.01	-40.21	41.80	38.85	34.75	-21.11	-12.18	3.68	-278.16	
(12)	Flow	200	(SW)	9.30	8.40	8:30	9.00	9.30	9.00	9.30	9.30	9:00	9.30	9.00	9.30	109.50	
£	Total Use	(240 actes)	(OIM)	5.37	19.54	28,34	38.57	44.31	49.21	51.10	49.25	43.75	30.41	21.18	5.64	387.66	
<u>(</u>	MMAV	Maka	(MG)	2.24	8.14	12.22	16.07	18.46	20.50	21.29	20.52	18.23	12.67	8.82	235	161.53	
<u>. </u>	MMAV	Mauka	(140 Bc) (MG)	3.13	11.40	17.11	22.50	25,84	28.70	29.81	28.73	25,52	17.74	12.35	3.29	226.14	
e	MMAR	Make	(inches)	0.82	3.00	4.50	5.92	6.80	7.55	7.84	7.56	6.71	4.67	325	0.87	59.47	
ε	MMAR	Mauka	(inches)	0.82	300	4.50	262	680	7.55	7.84	7.56	6.71	4.67	325	0.87	59.47	
9	DMPR	Makei	(inches)	187.49	160 34	187 40	181.44	187 49	181 44	187.49	187.49	181.44	187.49	181.44	187.49	2207.52	
(2)	DMPR	Mauka	(inches)	٤	8 8	3 8	38	8 8	200	8 8	8 8	8 8	3 6	88	800	0.00	
(4)	ٔ تتا	Makei	(Inches)	8	CC.7	9 6	7.34	92.4	200	0.00 0.35	0.00 2.00	7.55	8. 9	25. A	4.57	81.20]
(2)	ᇤ	Mauka	(inches)		207	9 70	100	2.4	2 2	9.05	200	7.50	8.5	90.90	4.57	81.20	
(2)	Precip.	at Kekaha	(inches)		- 9	2.40	7.	74.	2 7	7 10	10.0	6,50	200		3 25	21.77	
ε	Pan Evap.	at Kekaha	(Inches)	1	ţ, c	5 G	6.31	0.0	2 2	3 5	3	6.5	9 9	0 0	4.03	73.53	
	4	TINDE			3	9 !	XX.	¥ :	MA.	NO.	7	S G	7 6	5 5	2 2	ANNUAL	1
	(2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14)	(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14) Pan Evap. Precip. ET ET DMPR DMPR MMAR MMAR MMAV Total Use Flow Surplus Cumulative S	(2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14) Precip. ET ET DMPR DMPR MMAR MMAR MAKAV MMAV Total Use Flow Surplus Cumulative Sat Kekaha Mauka Mauka Makai Mauka Mauka Makai Mauka Ma	(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14) Pan Evap. Precip. ET ET DMPR Makei Mauka Makei Mauka Makei Mauka Makei (100 sc) (100	(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (12) (13) (14) (14) (15) (14) (15) (15) (15) (15) (15) (15) (15) (15	(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (12) (13) (14) (14) (14) (15) (15) (15) (15) (14) (15) (15) (15) (15) (15) (15) (15) (15	(1) (2) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (12) (13) (14) (14) (14) (15) (15) (14) (15) (15) (15) (15) (15) (15) (15) (15	(1) (2) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (12) (13) (14) (14) (14) (15) (15) (15) (15) (15) (15) (15) (15	The column The	(1) (2) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (12) (13) (14) (14) (15) (15) (15) (15) (15) (15) (15) (15	(1)	(1)	The color Car Car	(1) (2) (2) (3) (4) (5) (6) (7) (9) (10) (11) (12) (12) (13) (14) (14) (14) (15) (14) (14) (15) (15) (1	(1) (2) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (12) (13) (14) (14) (15) (14) (15	(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (12) (13) (14) (14) (14) (15) (15) (1	The color Car Car

TABLE 14. WATER BALANCE FOR SCENARIO 3

FUTURE FLOW RATE = 600,000 GPD PASTURE MAUKA AND MAKAI OF HIGHWAY

	(15)	Storage Volume (MG)	000	
	(14)	Cumulative sur/def (MG)	495.89 -958.67 -1478.63 -1891.89 -2528.91 -3650.91 -3692.62 -4132.49 -4651.03 -5172.06 -5668.03 -6164.29	
	(13)	Surplus Deficit (MG)	495.89 462.68 519.86 513.36 524.00 524.00 541.72 539.86 510.3 495.97	-6164.29
	(12)	Flow 0.3 MGD (MG)	8.81 8.82 8.83 8.83 8.83 8.83 8.83 8.83 8.83	219.00
	(H)	Total Use (240 acres) (MG)	514.59 479.48 538.56 531.38 553.52 542.00 560.32 558.46 536.54 536.54 539.63 513.97 514.86	6383.29
	(0)	MIMAV Makai (100 ac) (MG)	511.46 468.08 521.44 508.86 527.68 513.29 530.51 529.74 511.02 501.62	6157.15
~	(6)	MMAV Mauka (140 ac) (MG)	3.13 11.40 17.11 22.50 25.84 28.70 28.73 28.73 25.52 17.74 12.35 3.28	226.14
COLATION	<u>(8)</u>	MMAR Makai (inches)	188.31 172.34 191.39 197.36 194.29 195.33 195.04 188.15 192.15 188.15	2266.99
MITH PERCOLATION	3	MMAR Mauka (Inches)	0.82 3.00 4.50 6.82 7.53 7.54 7.54 7.54 7.57 9.75 9.75 9.75 9.75 9.75 9.75 9.75	4.8
>	(9)	DMPR Makal (Inches)	187.49 169.34 187.49 187.49 187.49 187.49 187.49	ZC:1/27
	(2)	DMPR Mauka (inches)	888888888888888888888888888888888888888	3
j	(4)	ET Makai (inches)	8.35 8.35 8.35 8.35 8.31 7.50 8.31 7.50 8.35 8.35 8.35 8.36 8.36 8.36 8.37	23.10
	(6)	ET Mauka (Inches)	8.55 8.31 8.31 8.31 8.31 8.31 8.31 8.31 8.31	
3	(2)	Precip. at Kekaha (inches)	2.48 2.44 1.42 0.98 0.47 0.75 0.75 0.79 1.89 2.13 3.70	
	ε	Pan Evap. at Kekaha (inches)	4.54 4.98 6.67 7.07 7.29 7.29 7.55 7.55 6.82 6.82 6.82 6.82 7.55 6.82 6.82 7.55 6.82 7.55 6.82 7.55 6.82 7.55 6.82 7.55 6.82 7.55 6.82 7.55 6.82 7.55 6.82 7.55 6.82 7.55 6.82 7.55 7.55 7.55 7.55 7.55 7.55 7.55 7.5	
		Month	JAN FEB MAR APR JUN JUL AUG SEP OCT · DEC	

	(15)	Storage Volume (MG)	28.19 23.45 2.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	15.90
	(14)	Cumulative sur/def (MG)	13.23 10.49 20.02 20.02 46.53 11.02 140.88 118.63 18.63 18.63	3
	(13)	Surplus Deficit (MG)	13.23 47.2- 10.7- 20.57 12.12- 3.12- 3.06- 3.13-	-168.66
	(12)	Flow 0.3 MGD (MG)	8.81 8.82 8.83 8.83 8.83 8.83 8.83 8.83 8.83	219.00
	(11)	Total Use (240 acres) (MG)	5.37 19.54 29.34 38.57 48.31 51.10 51.10 49.25 43.75 51.18	387.66
	(0)	MMAV Makel (100 ac)	224 8.14 16.07 18.05 20.50 20.52 20.52 18.23 12.67 2.35	161.53
NO	(6)	Mauka (140 ac) (MG)	3.13 11.40 17.11 25.50 25.84 28.70 28.73 26.73 25.52 17.74 17.74	226.14
RCOLATI	(9)	MMAR Makai (inches)	0.82 3.00 4.50 5.92 6.89 7.55 7.54 7.56 7.56 7.56 7.56 7.56 7.56 7.56 7.56	59.47
WITHOUT PERCOLATION	ω	MMAR Mauka (Inches)	0.82 3.00 5.45 6.59 6.80 7.58 7.78 7.78 7.78 8.71 8.71 8.71 8.00 9.00 9.00 9.00 9.00 9.00 9.00 9.00	59.47
₩	(9)	DMPR Makai (inches)	888888888888888888888888888888888888888	0.00
	(2)	OMPR Mauka (inches)	888888888888888888888888888888888888888	0.00
	(4)	ET Makai (inches)	8.35 8.31 8.35 8.35 8.31 8.31 8.31 8.31 7.50 8.31 7.50	81.20
·	(6)	ET Mauka (inches)	4.99 5.48 6.94 7.78 8.35 7.50 6.56 6.56	81.20
	(z)	Precip. at Kekaha (Inches)	2.48 2.44 1.42 0.08 0.51 0.75 0.75 1.89 2.13 3.70	21.77
	Ê	Pan Evap. at Kekaha (inches)	4.54 6.64 7.70 7.70 7.70 7.70 7.70 7.70 7.70 7.7	73.53
, 	,	Month	JAN MAR APR JUN AUG SEP OCT	ANNUAL

TABLE 15. WATER BALANCE FOR SCENARIO 4

CURRENT FLOW RATE = 300,000 GPD TURF MAUKA OF HIGHWAY AT PARK ONLY

WITH PERCOLATION

				- 1
	Volume (MG)		6.55 7.70 8.63 9.31 9.94 10.67 11.57 13.23 15.26	
	Cumulative sur/def (MG)	 	6.55 7.70 8.68 9.31 9.94 11.57 11.57 13.23 15.26	
<u> </u>	Surplus Deficit (MG)		1,72 1,16 0,97 0,63 0,63 0,73 0,90 1,67 2,03 2,03 2,03	
(21)	Flow 0.3 MGD (MG)		9.30 9.30 9.30 9.30 9.30 9.30 9.30 9.30	
E	Total Use (12 acres) (MG)	6.38	6.50 7.58 7.58 8.33 8.37 8.67 8.67 7.63 6.97 6.93	
<u> </u>	MIMAV Makal (0 ac)	٤	00:0 00:0 00:0 00:0 00:0 00:0 00:0	
6	MMAV Mauka (12 ac)	٤	6.50 7.58 8.33 8.33 8.67 8.67 8.10 8.10 8.10 8.10 8.10 8.10 8.10 8.10	1 _
(8)	MMAR Makai (inches)	1_		280.22 22.083 20.12 2.00.33
3	MMAR Mauka (inches)	.		!
(9)	DMPR Makai (inches)	707	169.34 187.49 181.44 187.49 187.49 187.49 187.49 187.49	2207.52
(5)	DMPR Mauka	(minus)	18.75 16.93 18.75 18.14 18.75 18.75 18.75 18.75	220.75
(4)	ET Makai	(Inclies)	4.99 5.48 6.94 7.34 7.78 8.02 8.35 8.31 7.50 6.56 6.56	81.20
100	ET Mauka	(inches)	6.99 6.94 7.34 7.78 8.02 8.35 8.31 7.50 6.56 6.56	81.20
	(2) Precip. at Kekaha	(inches)	2.48 2.48 2.44 1.42 0.98 0.75 0.75 0.79 1.89 2.13	21.77
	(1) Pan Evap. at Kekaha	(inches)	4.54 4.98 6.31 6.67 7.07 7.29 7.59 7.59 6.82 6.82 6.82 6.82 6.82 6.82 6.82 6.82	73.53
 	Month		JAN MARR APR JUL JUL AUG SEP OCT	ANNUAL

(45)	2	Storage	Volume (MG)	9.03	16.45	24.29	38.44	44.98	58.57	65.38	81.10	80.13	_		
	(41)	Cumulative	sur/def (MG)	9.03	16.45	24.29	38.44	44.98	58.57	65.38	81.10	90.12	_		
	(13)		Deficit (MG)	506	7.42	7.83	7.08	6.54	6.84	6.81	7.78	9.05	80.12		
	(12)	Flow	0.3 MGD (MG)			9.30							Ţ	4	
	(11)	Total Ilea	(12 acres) (MG)	200	0.20	1.47	1.83	2.46	255	2.19	53.5	8.0	9, 0	8:6	,
	(10)		Makai (0 ac)	Ξ		8 8							1	3	
ź	6	2	MMAV Mauka (12 ac)	(SWG)		0.98								19.38	
	Į į	 9	MIMAR Makai (inches)			3.00							4	59.47	
		<u> </u>	MMAR Mauka (inches)			3.00							_	59.47	1
3	1	<u> </u>	OMPR Makai (inches)			0.0									
		(2)	DMPR Mauka	7	8	900	0.00	0.00	8.5	0.0	88	000	0.0	18	3
		£	ET Makai	(sales)	3	5.48	6.94	7.78	8.02	8.31	7.50	2 S	4.57	1	81.20
		(2)	ET Mauka	(inches)		5.48	6.94	7.78	8.02	8.9 8.31	7.50	6.56	S 5		81.20
		(2)	Precip. at Kekaha	(inches)		4.17	2.44	1.42	0.47	0.51	0.79	1.89	2.13	3	21.77
		ε	Pan Evap. at Kekaha	(inches)		4.54	6.31	6.67	7.28	7.59	6.82	5.96	4.89	4.15	73.53
			Month			SAS E	MAR	APR	N N		AUG	ğ	NOV	CHO	ANNIAL

TABLE 16. WATER BALANCE FOR SCENARIO 4

FUTURE FLOW RATE = 600,000 GPD TURF MAUKA OF HIGHWAY AT PARK ONLY

WITH PERCOLATION

						_			_		_			_			
(15)	Storage	Volume	(MG)		1222	22.52	33.55	43.70	53.98	63.61	73,54	83.57	93.47	104.43	115.46	127.67	
(14)	Cumulative	sur/def	(MG)		12.22	22.52	33.55	43,70	53.98	63.61	73,54	83.57	93.47	104.43	115.46	127.67	
(13)	Surplus	Deficit	(MG)		12.22	10.30	11.02	10.16	10.27	9.63	9.93	10.03	9.90	10.97	1.8	12.21	127.67
(12)	Flow	0.6 MGD	(MG)		18.60	16.80	18.60	18.00	18.60	18.00	18.60	18.60	. 18.00	18.60	18.00	18.60	219.00
(11)	Total Use	(12 acres)	(MG)		6.38	6.50	7.58	7.84	8.33	8.37	8.67	8.57	8.10	7.63	6.97	6:33	91.33
(10)	MMAV	Makal	(0 gc)	(MG)	8.0	000	00.0	000	0.0	00:0	0.0	00.00	0.0	000	000	00.00	0.00
(6)	MMAV	Mauka	(12 ac)	(MG)	6.38	6.50	7.58	7.84	8.33	8.37	8.67	8.57	8.10	7.63	6.97	6.39	91.33
(8)	MMAR	Makai	(inches)		188.31	172.34	191.99	187.36	194.29	188.99	195.33	195.04	188.15	192.15	184.69	188.35	2266.99
ω	MMAR	Mauka	(Inches)		19.57	19.93	33.32 33.32	24.06	25.55	25.69	26.59	26.30	24.86	23.41	21.39	19.61	280.22
(9)	DMPR	Makal	(Inches)		187.49	169.34	187.49	181.44	187.49	181.44	187.49	187.49	181.44	187.49	181.44	187.49	2207.52
<u>(S</u>	DWPR	Mauka	(inches)		18.75	16.93	18.75	18.14	18.75	18.14	18.75	18.75	18.14	18.75	18.14	18.75	220.75
(4)	ᇤ	Makai	(Inches)		6.8	5.48	6.94	7.34	7.78	8.02	8.35	8.31	7.50	6.56	5.38	4.57	81.20
(3)	ш	Mauka	(Inches)		4.99	5.48	6.94	7.34	7.78	8.02	8.35	8.31	7.50	6.56	5.38	4.57	81.20
(2)	Precip.	at Kekaha	(Inches)		4.17	2.48	2.44	1.42	96.0	0.47	0.51	0.75	0.79	88.	2.13	3.70	21.77
ε	Pan Evap.	at Kokaha	(Inches)		4.54	4.88	6.31	6.67	7.07	7.29	7.59	7.55	6.82	5.96	4.89	4.15	73.53
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	(15)	Storage	Volume	(MG)	18.3	34.1	51.23	67.3	83.7.	89.2	115.3	131.4	147.2	164.3	181.3	199.62	
	(14)	Oumulative	sur/def	(MG)	18.33	34.15	51.23	67.36	83.74	99.28	115.33	131.47	147.28	164.36	181.30	189.62	
	(13)	Surplus	Deficit	(MG)	18.33	15.82	17.13	16.07	16.38	15.54	16,05	16.14	15,81	17.08	16.94	18.32	199.62
	(15)	Flow	0.6 MGD	(MG)	18.60	16.80	18.60	18.00	18.60	18.00	18.60	18.50	18.00	18.60	18.00	18.60	219.00
	(11)	Total Use	(12 acres)	(WC)	0.27	0.98	1.47	1.83	2:22	2.46	2.55	2.46	2.19	1.52	1.06	0.28	19.38
	(10)	MMAV	Makai	(0 ac) (MG)	0:00	00:0	000	000	0.0	00.0	000	0.00	0.00	000	000	0.00	00.00
2	(6)	MMAV	Mauka	(12 ac) (MG)	0.27	96'0	1.47	1.93	2.22	2.46	2.55	2.46	219	1.52	1.06	0.28	19.38
3	(6)	MIMAR	Makai	(inches)	0.82	300	4.50	5.92	6.80	7.55	7.84	7.56	6.71	4.67	3.25	0.87	59.47
	۵	MMAR	Mauka	(Inches)	0.82	3.00	4.50	5.92	6.80	7.55	7.84	7.56	6.71	4.67	3.25	0.87	59.47
*	(9)	DMPR	Makal	(inches)	00:0	00:0	0.00	800	0.00	8.0	0.00	0.00	0.00	0.00	0.00	0.00	00'0
	(2)	DMPR	Mauka	(inches)	00'0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(4)	ᇤ	Makai	(inches)	4.99	5.48	6.94	7.34	7.78	8.02	8.35	8.31	7.50	6.56	5.38	4.57	81.20
	(e)	ᇤ	Mauka	(inches)	4.99	5.48	6.94	7.34	7.78	8.02	8.35	8.31	7.50	6.56	5.38	4.57	81.20
	(z)	Precip.	at Kekaha	(inches)	4.17	2.48	244	1.42	86.0	0.47	0.51	0.75	62.0	1.89	2.13	3.70	21.77
	(1)	Pan Evap.	at Kekaha	(Inches)	4.54	4.98	6.31	6.67	7.07	23.7	7.59	7.55	6.82	5.96	4 .83	4.15	73.53
		Month			JAN	FEB	MAR	APR	MAY	NOT NOT	를 -	AUG	SEP	င်	ò	SEC	ANNUAL

The following section is a sample "walk through" of Table 9. All sample calculations were determined for the month of February.

- Col. (1): Mean Monthly Pan Evaporation in Kekaha at Station 944.00. (See Table 3.)
- Col. (2): Mean Monthly Precipitation in Kekaha at Station 944.00. (See Table 3.)
- Col. (3): ET = Evapotranspiration rate of the crop mauka of the highway.

 The ET rate for sugar cane using drip irrigation is approximately 75% of the pan evaporation. This rate was obtained from Technical Report No. 109, "Drip Irrigation of Sugarcane Measured by Hydraulic Lysimeters, Kunia, Oahu", by Paul C. Ekern, dated June 1977, from the Water Resources Research Center at the University of Hawaii. (ET rate for seed corn is 60% of the pan evaporation.)

$$ET_{Feb} = 4.98 \text{ in x .75} = 3.74 \text{ inches}$$

Col. (4): ET rate of the crop makai of the highway. For all three alternatives, this crop will be pasture. The ET rate for Bermuda grass is given in the DOH guidelines as approximately 110% of the pan evaporation.

$$ET_{Feb} = 4.98 \text{ in x } 1.10 = 5.48 \text{ inches}$$

Col. (5): DMPR = Design Monthly Percolation Rate, which is based on 4% to 10% of the minimum soil permeability. Percentages on the lower end of the scale are recommended for variable or poorly defined soil conditions. For the purpose of this report, a conservative value of 4% is used.

DMPR = permeability (in/hr) x 24 hr/day x (4%) x No. of operating days/month.

Since the reclamation area mauka of the highway consists of several soil types, the most limiting soil horizon was determined from the soil survey information. The most limiting soil is Kaloko Clay (Kfa) with a permeability of 0.06 to 0.63 in/hr. Since this permeability is lower than that recommended by DOH (DOH recommends 0.6 to 6.0 in/hr) and a large portion of the reclamation area is filled land (Fd), which does not have a given permeability, the DMPR was calculated with the permeability component equal to zero. This will result in a conservative value for the application rate.

Col. (6): DMPR makai of the highway was determined using the permeability rate for Jaucas Sand (JkB), which is the principal soil type. The permeability rate is 6.3 to 20.0 in/hr. DOH recommends using the most conservative value from the range of permeability. Therefore, a rate of 6.3 in/hr was used to calculate the DMPR.

DMPR_{Feb} = 6.3 in/hr x 24 hr/day x .04 x 28 days
=
$$\frac{169.34 \text{ inches}}{}$$

Col. (7): MMAR = Maximum Monthly Application Rate for each month for the crop mauka of the highway.

MMAR = ET - Precipitation + DMPR + Runoff
MMAR_{Feb} =
$$3.74 \text{ in - } 2.48 \text{ in + } 0 + 0 = \underline{1.26 \text{ inches}}$$

Col. (8): MMAR for the crop makai of the highway.

Col. (9): MMAV = Maximum Monthly Application Volume for area mauka of the highway.

MMAV = MMAR x 140 acres x 0.02716 MG/acre-in

$$MMAV_{Feb}$$
 = 1.26 in x 140 ac x 0.02716 MG/acre-in
= 4.8 MG

Col. (10): MMAV = Maximum Monthly Application Volume for area makai of the highway.

MMAV = MMAR x 100 acres x 0.02716 MG/acre-in

 $MMAV_{Feb} = 172.34 \text{ in x } 100 \text{ ac x } 0.02716 \text{ MG/acre-in}$ = 468 MG

Col. (11): Total Use = Total MMAV for areas mauka and makai of the highway.

Total Use_{Feb} = 4.77 MG + 468.08 MG = 472.85 MG

Col. (12): Flow = Design flow from the Waimea WWTP (current).

Flow = 300,000 gpd x 28 days / 1,000,000 = 8.4 MG

Col. (13): Surplus/Deficit = Surplus or deficit of the effluent. A negative value represents a deficit.

Surplus/Deficit = Flow - Total Use

Surplus/Deficit_{Feb} = 8.40 MG - 472.85 MG = $\frac{-464.45 \text{ MG}}{}$

Col. (14): Cumulative surplus/deficit is the cumulative surplus or deficit over the length of the year.

Cum. $sur/def_{Feb} = -502.16 MG + -464.45 MG$ = -966.61 MG

Col. (15): Storage Volume required for storage of effluent. No storage is required since there is a cumulative deficit.

An alternative to establishing pastures makai of the highway for the first three scenarios is to plant turf. Although the irrigation rate for turf is expected to be about the same as that for pastures, the cost of the irrigation system would be significantly higher — about \$7,000/acre for turf vs. \$3,000/acre for pastures.

(Turf irrigation is more expensive because the drip lines are closer together to provide more even watering required for higher quality grass.) Therefore, planting turf — as well as accompanying landscaping — was not explicitly included in the water balance tables for the first three scenarios evaluated. However, the water balance results — if portions of the area makai of the highway were to be planted with turf — would be the same as that indicated for the alternative of all makai areas being in pasture.

The following conclusions can be drawn from the water balance tables:

- The primary controlling factor for maximum usage of reclaimed water is inclusion of the design monthly percolation rate (DMPR) for areas makai of the highway (Column 6 in tables). Inclusion should be acceptable to DOH, since the area is makai of their UIC Line.
- Based on inclusion of the DMPR, no backup storage is required for any
 of the first three scenarios, even at the future flow rate of 600,000 gpd.
 However, it would still be prudent to construct a new albeit relatively
 small reservoir.
- halves of tables, labeled "Without Percolation" are used then the only scenario that could possibly be accommodated, with the existing 8± MG lower reservoir being the sole backup, would be Scenario 3 (pastures both mauka and makai of highway), and only at the current flow rate of 300,000 gpd. The reason that Scenarios 1 and 2 could not be accommodated is that the evapotranspiration rates for sugar cane and seed corn are 75% and 60%, respectively, of the pan evaporation rate, as compared to 110% for pasture.
- Scenario 4 would not be viable due to the large effluent storage requirements. The area of available land, only 12 acres, is not enough for disposal of all the effluent. However, if this scenario is combined

with irrigation makai of the highway, and the DMPR is included, then only a small reservoir would be required for backup storage.

The estimated construction costs associated with the four scenarios are presented in Tables 17-20. The common components to all four scenarios are as follows:

Modification of lower reservoir. This existing 8± MG open reservoir must be lined to be in conformance with DOH's water reclamation guidelines. It is proposed that the lining material be 45 mil Hypalon. An alternative to lining this existing reservoir would be to construct a new smaller reservoir — either a similar open-type reservoir or a tank. The justification for the smaller size would be the zero backup storage volume required when percolation is considered (See Tables 9-16). Much more in-depth analysis, as part of a Basis of Design Report — which is beyond the scope of this study — would be required to obtain DOH approval for downsizing the reservoir. Even if DOH approved a lesser storage volume, a problem may be determination of a site that can be integrated into Kikiaola's Master Plan.

The excavation cost for a new reservoir could readily offset the savings associated with lining of such a smaller reservoir. Therefore, the \$380,000 cost in Table 16 should be used for planning purposes as part of this study.

- HDPE transmission line. The concept is to install high density polyethylene (HDPE) pipe along existing roads from the WWTP to the control valves for each irrigation control station.
- Central pumping and filtration station and control center. This
 component would be located at the WWTP. (See Exhibit 7, Site Plan,
 and Exhibit 8, Hydraulic Profile.) The concept is to boost the pressure
 of the reclaimed water from the existing 10" force main either water
 that is being pumped concurrently out of the effluent pump basin or

stored water flowing by gravity out of the lower reservoir — using a duplex booster pump system. The discharge from this booster pump system would pass through pressure filters prior to being conveyed, via the HDPE transmission lines, to the various areas being irrigated.

- Irrigation control system. This system would automatically activate the control valves at each of the irrigation control stations.
- Sub-surface drip irrigation systems for reuse areas. The cost of irrigation systems for sugar cane, seed corn, pasture and turf range in price from \$1,800 per acre to \$7,000 per acre. The price is largely dependent upon the crop row spacing.

Temporary drip irrigation systems that are destroyed during harvesting would, more than likely, be installed for sugar cane and seed corn cultivation. "Permanent" drip irrigation systems would be installed for pastureland and turf/landscaping areas. The cost of both the temporary and permanent drip systems would be paid for by the County.

TABLE 17. ESTIMATED CONSTRUCTION COST FOR MODIFICATION OF LOWER RESERVOIR

DESCRIPTION		MATED INTITY	UNIT PRICE	TOTAL
Clearing and Grubbing	3.3	Acres	\$5,000.00	\$16,500
Rough Grading		Lump Sum		\$20,000
Fine Grading	150,000	SF	\$0.25	\$37,500
	150,000	SF	\$1.00	\$150,000
Lining	1,700	LF	\$40.00	\$68,000
Fencing Miscellaneous items		Lump Sum		\$50,000
Wiscondine Ode Romo		10% CC	SUBTOTAL NTINGENCY	\$342,000 34,200
	<u> </u>		TOTAL	\$376,200
	SAY	\$380,000		

TABLE 18. ESTIMATED CONSTRUCTION COST FOR SCENARIO 1 IRRIGATION SYSTEM WITH SUGAR CANE MAUKA OF HIGHWAY AND PASTURES MAKAI OF HIGHWAY

DESCRIPTION	ESTIMATED QUANTITY		UNIT PRICE	TOTAL
HDPE Transmission Line mauka of highway	6,200	ĹF	\$15.00	\$93,000
HDPE Transmission Line makai of highway	5,800	LF	\$15.00	\$87,000
Central Pumping and Filtration Station and Control Center		Lump Sum		\$150,000
Irrigation Control System		Lump Sum		\$20,000
Subsurface Drip Irrigation for Sugar Cane mauka of highway	140	Acres	\$1,700.00	\$238,000
Subsurface Drip Irrigation for Pasture makai of highway	100	Acres	\$3,000.00	\$300,000
SUBTOTAL 10% CONTINGENCY				\$888,000 88,800
			TOTAL	\$976,800
. SAY				\$980,000

TABLE 19. ESTIMATED CONSTRUCTION COST FOR SCENARIO 2 IRRIGATION SYSTEM WITH SEED CORN MAUKA OF HIGHWAY AND PASTURES MAKA! OF HIGHWAY

DESCRIPTION	ESTIMATED QUANTITY		UNIT PRICE	TOTAL
HDPE Transmission Line mauka of highway	6,200	LF	\$15.00	\$93,000
HDPE Transmission Line makai of highway	5,800	ᄕ	\$15.00	\$87,000
Central Pumping and Filtration Station and Control Center		Lump Sum		\$150,000
Irrigation Control System		Lump Sum		\$20,000
Subsurface Drip Irrigation for Seed Corn mauka of highway	140	Acres	\$2,000.00	\$238,000
Subsurface Drip Irrigation for Pasture makai of highway	100	Acres	\$3,000.00	\$300,000
SUBTOTAL 10% CONTINGENCY				\$930,000 93,000
TOTAL				\$1,023,000
SAY				\$1,100,000

TABLE 20. ESTIMATED CONSTRUCTION COST FOR SCENARIO 3 IRRIGATION SYSTEM WITH PASTURES MAUKA AND MAKAI OF HIGHWAY

DESCRIPTION	ESTIMATED QUANTITY		UNIT PRICE	TOTAL
HDPE Transmission Line mauka of highway	6,200	LF	\$15.00	\$93,000
HDPE Transmission Line makai of highway	5,800	LF	\$15.00	\$87,000
Central Pumping and Filtration Station and Control Center		Lump Sum		\$150,000
Irrigation Control System		Lump Sum		\$20,000
Subsurface Drip Irrigation for Pasture mauka of highway	140	Acres	\$3,000.00	\$420,000
Subsurface Drip Irrigation for Pasture makai of highway	100	Acres	\$3,000.00	\$300,000
	\$1,070,000 107,000			
TOTAL				\$1,177,000
. SAY				\$1,200,000

TABLE 21. ESTIMATED CONSTRUCTION COST FOR SCENARIO 4 IRRIGATION SYSTEM WITH TURF MAKAI OF HIGHWAY AT WAIMEA PARK

DESCRIPTION	ESTIMATED QUANTITY		UNIT PRICE	TOTAL
HDPE Transmission Line mauka of highway	2,500	LF	\$15.00	\$38,000
Central Pumping and Filtration Station and Control Center		Lump Sum		\$150,000
Irrigation Control System		Lump Sum		\$20,000
Subsurface Drip Irrigation for Turf makai highway at Walmea Park	12	Acres	\$7,000.00	\$84,000
SUBTOTAL 10% CONTINGENCY				
TOTAL				\$321,200
SAY				\$330,000

D. Other Alternatives

The following additional alternatives for effluent reuse/disposal were considered:

- Disposal of effluent via ocean outfall. This alternative is expected to be significantly more expensive to implement. Although a detailed analysis would be required to establish the length of the outfall, as well as other cost-related factors, it would be reasonable to assume that the outfall discharge would have to be at least a mile offshore. The associated cost would then be over \$10 million (5,280 L.F. @ \$2,000/L.F.).
- Irrigation reuse of reclaimed water at Waimea High School or Hospital. This turf/landscaping alternative was deemed unsatisfactory because the actual size of the landscaped area is quite small, and would not provide enough area for application of the effluent. Another disadvantage of irrigating at the school or hospital is that these types of establishments are known to be high public utilization areas. Although

Pumpage of reclaimed water up to Kekaha Ditch, rather than to the lower reservoir, for irrigation reuse throughout the upper fields (i.e., 250± acres above the UIC line), and/or Kekaha land. This alternative would require 2,000± L.F. of new force main from the existing reservoirs to Kekaha Ditch, and either higher head effluent pumps at the WWTP or a booster pump system at the reservoirs. Besides the capital cost associated with this new force main and pump system is the power cost of lifting the effluent an additional 400+ feet. Assuming an additional 400 feet of head and 600,000 gpd of effluent, the additional power cost would be \$50,000± per year.

A second option would be to pump to the lower, Waimea Ditch, which is currently not being utilized. This option would be for irrigation of Kekaha land and/or Kikiaola land. However, most of Waimea Ditch is located within Kikiaola land. Consequently, if Kikiaola does not renew their lease with Kekaha, then the effluent may have to be pumped to the portion of Waimea Ditch which lies within Kekaha land. This option would require a new force main (8,000± L.F.) from the existing reservoir to Waimea Ditch at the border between Kikiaola and Kekaha land. The force main would most likely be located mauka of Waimea Ditch within State land. The power cost for this option would be lower than the Kekaha Ditch option (approximately \$6,000 per year), since the elevation of Waimea Ditch is much lower than Kekaha Ditch.

The areas irrigated with both of these option is above the UIC Line, which would require stricter DOH conditions, including groundwater monitoring requirements. In further discussions with Kekaha, they indicated their rejuctance to accept the effluent due to these stricter requirements. Therefore, a cost analysis of these two options was not pursued.

IX. CONCLUSIONS AND RECOMMENDATIONS

The feasibility of several alternatives for reuse/disposal of effluent from the Waimea WWTP were considered in this report. A brief summary of each alternative follows.

Renegotiation of the Current Disposal Agreement.

A meeting was held on December 7, 1993 at the County of Kauai to discuss the proposed alternatives for effluent reuse/disposal. The meeting was attended by representatives from the County, Austin, Tsutsumi & Assoc., and Kikiaola. At this meeting, Kikiaola expressed their stance on the proposed reuse alternatives as follows:

- The agreement between the County and Kikiaola will not be extended on a long-term basis. Kikiaola is applying in April of 1994 for a residential subdivision permit for development of the area where the lower effluent reservoir is situated, which would entail eliminating the reservoir. Based on the time required to process the permit, and to design and construct the subdivision, it was estimated that the reservoir may not be available for the County's use as early as the end of 1995.
- Kikiaola is planning on leasing their land to the highest bidder after their lease with Kekaha expires. Due to the fact that seed corn generally pays more than sugar cane, seed corn will be the predominant crop cultivated. Most of Kekaha's crops will be harvested in late 1994, with the remaining crops harvested in late 1995. Therefore, new leases between the County, Kikiaola and the crop growers would be necessary by the end of 1994 to continue irrigation with effluent.

Due to the uncertainty of some aspects of this alternative – e.g., how long the lower reservoir will be available and new lease agreements – the County should not depend on continuance of the current effluent disposal method on a

long-term basis. Therefore, a more permanent means of effluent reuse/disposal should be actively pursued by the County.

B. Golf Course Irrigation

This alternative would only apply if Kikiaola's Master Plan is implemented. However, Kikiaola stated at the December 7 meeting that they would require the effluent to be treated to R-1 standards, which would require significant upgrades to the Waimea WWTP. Advanced treatment necessary to achieve R-1 quality water would involve chemical addition and filtration, and would require a much larger chlorine contact tank — for an effective chlorine contact time of 120 minutes. The anticipated cost of upgrading the WWTP to produce R-1 water is approximately one million dollars for a wastewater flow rate of 600,000 gpd.

A supplemental study on further expansion of the WWTP and the effluent reuse/disposal system would be required. Also, a new agreement between the County and Kikiaola would be necessary.

Since the time frame for the implementation of Kikiaola's Master Plan is uncertain, this alternative should not be pursued as a means of immediate reuse/disposal of the effluent. However, this alternative may be a means of effluent reuse in the future.

C. Ocean Outfall

This alternative should not be pursued due to the high cost associated with construction of the outfall of over \$10 million.

D. Subsurface Disposal Via Injection Wells (No Reclamation)

Implementation of this alternative would require construction of two injection wells at the site of the existing WWPS 'A'. Each well would have a capacity of 1.2 mgd, which is the future average flow rate of 600,000 gpd times a peak factor of 2.0. Nutrient removal - primarily nitrogen and phosphorus - will not be required by the State for their issuance of injection well permits.

By disposing all of the effluent via injection wells located on County property, the need to negotiate agreements with Kikiaola - i.e., to store effluent in the existing reservoir and reuse for irrigation on Kikiaola Land - would be eliminated.

E. Irrigation Reuse for Crops or Pastures

This alternative would use irrigation as the primary means of effluent disposal, with either a storage reservoir or an injection well as a backup. However, as previously mentioned, the lower effluent reservoir may be eliminated as early as the end of 1995. A possible solution would be to construct a new reservoir near the WWTP. Unfortunately, Kikiaola is planning on developing the land around the WWTP for residential units, a sports complex and green areas, such as a golf course and horse trails. Consequently, there is no logical place for a new reservoir to be located. Hence, an injection well will most likely be required as a permanent backup disposal unit for the effluent.

Three different alternatives of crop combinations for effluent reuse were considered viable:

Scenario 1: Sugar cane cultivation mauka of the highway, and pasture makai of the highway.

Scenario 2: Seed corn cultivation mauka of the highway, and pasture makai of the highway.

Scenario 3: Pasture mauka and makai of the highway.

A fourth scenario was considered which involved irrigation of turf at Waimea Park. However, the small amount of area available necessitated a large storage reservoir (much larger than the existing lower reservoir), and was thus, not considered feasible.

Water balance tables were calculated for the three scenarios, with and without consideration of design monthly percolation rates (DMPR), from which the following conclusions were drawn.

- If the DMPR is excluded from the calculations, and the existing lower reservoir is to be the sole backup, then pastures would have to be cultivated both mauka and makai of the highway, and only the current flow rate of 300,000 gpd could be accommodated.
- If the DMPR is excluded, and an injection well is to be the backup, then any of the scenarios could be implemented for the future flow rate of 600,000 gpd.
- If the DMPR is included in the calculations, then no large storage capacity (such as the existing lower reservoir) is required as a backup for any of the three scenarios, even at the future flow rate of 600,000 gpd. A smaller open reservoir or tank, however, would still be required.

Based on the valid argument that the DMPR should be considered, the most cost effective reclamation alternative would be to cultivate sugar cane mauka of the highway, establish pasture makai of the highway and use the existing reservoir for backup storage. But, this alternative would more than likely be only temporary, since the existing reservoir may be eliminated in the near future. Therefore, the most cost effective long-term alternative would be to construct an injection well for backup disposal, in lieu of the existing reservoir. Both of these alternatives would require that either the existing agreement between Kikiaola and the County be renewed, or a new agreement between these two parties be established.

Another important criteria for effluent reuse is Kikiaola's willingness to negotiate lease agreements with the County and the crop growers. However, Kikiaola stated at the meeting that the reuse alternatives would not be feasible unless the effluent is treated to R-1 standards. As stated previously, to construct a new chemical addition and filtration system, and a larger chlorine contact tank would cost approximately one million dollars for a wastewater flow rate of 600,000 gpd.

Due to the many uncertain aspect of this alternative — e.g., availability of lower reservoir, implementation of Kikiaola's Master Plan and their requirement for R-1 quality water — a long-term effluent reuse program involving irrigation of crops on Kikiaola land may not be viable. Therefore, it would be prudent for the County to pursue a more permanent means of effluent reuse/disposal.

F. SUMMARY OF COSTS

A summary of the estimated construction costs for the two main alternatives involving injection wells and/or reclamation systems is presented in Table 21.

TABLE 22. SUMMARY OF ESTIMATED CONSTRUCTION COSTS

	COST X \$1,000								
	NO RECLA- MATION	RECLAMATION							
		Scenario 1 Sugar Cane		Scenario 2 Seed Corn		Scenario 3 Pasture			
		w/res.	w/well	w/res.	w/well	w/res.	w/well		
Injection Well(s)	\$700	•••	\$350		\$350	•••	\$350		
Effluent Transmission Line	\$60	· .	\$60	•••	\$60	•••	\$60		
Modification of Lower Reservoir		\$380		\$380	•••	\$380			
Irrigation System		\$980	\$980	\$1,100	\$1,100	\$1,200	\$1,200		
TOTAL	\$760	\$1,360	\$1,390	\$1,480	\$1,510	\$1,580	\$1,610		

G. SELECTION OF ALTERNATIVE

A summary of the alternatives evaluated in this study, and advantages and disadvantages for each one, are presented in Table 1 (Section I. Executive Summary). Another criteria which should be considered during selection of an alternative is operation and maintenance of the system. There is very little maintenance required for injection wells. The wells would require routine cleaning

ATA.

approximately two or three times a year to prevent clogging. Typically, compressed air is forced down into the well and the upflow discharge is wasted (probably into SPS 'A' for pumpage to the WWTP). The cleaning process usually requires two men for a total of four hours.

A reuse system, on the other hand, is fairly labor intensive and would required the following operation and maintenance procedures:

- The central pumping and filtration station would require routine replacement and cleaning of the pumps and filters.
- The subsurface drip irrigation systems for sugar cane and seed corn would need to be replaced after every harvest.
- A monitoring system, with wells, would have to be maintained so that samples of the groundwater can be collected and analyzed for various constituents, such as chlorides, TDS, pH, and ammonia.

Based on the information presented in this study, it is recommended that the County pursue construction of injection wells for effluent disposal. This recommendation is based on the following criteria:

- Kikiaola's reluctance to accept effluent for reclamation reuse (once Kekaha's lease expires), unless R-1 quality water is provided.
- The uncertainty of the availability of the lower reservoir, and lack of a viable location for a new reservoir.
- Implementation of Kikiaola's Master Plan, which involves development of residential units and a golf course, in lieu of sugar cane and/or seed corn cultivation.
- The estimated construction cost for two injection wells is less than any reuse alternative.
- The operation and maintenance cost for injection wells is less than any reuse alternative.

 Injection wells could be constructed and operating as early as the beginning of 1995, whereas implementation of a reuse program conforming to DOH guidelines would likely take well over a year to obtain approval.

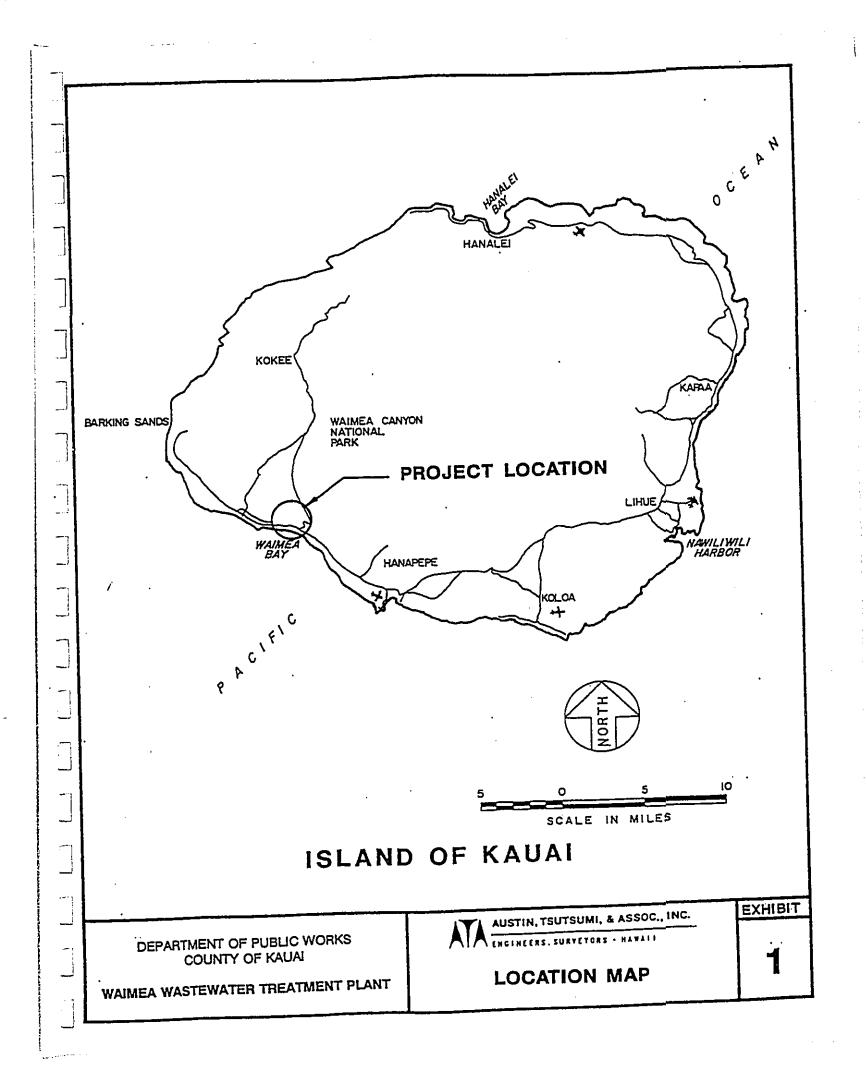
One injection well would be required (1.2 mgd capacity) when the lower effluent reservoir becomes unavailable. This well would be the backup disposal system if effluent reuse is continued until Kikiaola's Master Plan is implemented. If effluent reuse is eliminated all together, then a second well (1.2 mgd capacity) would be required. The two wells, at 1.2 mgd each, would provide for a 100 percent backup system for the future WWTP capacity flow rate of 600,000 gpd, without irrigation, based on a documented peak to average flow factor of 2.0.

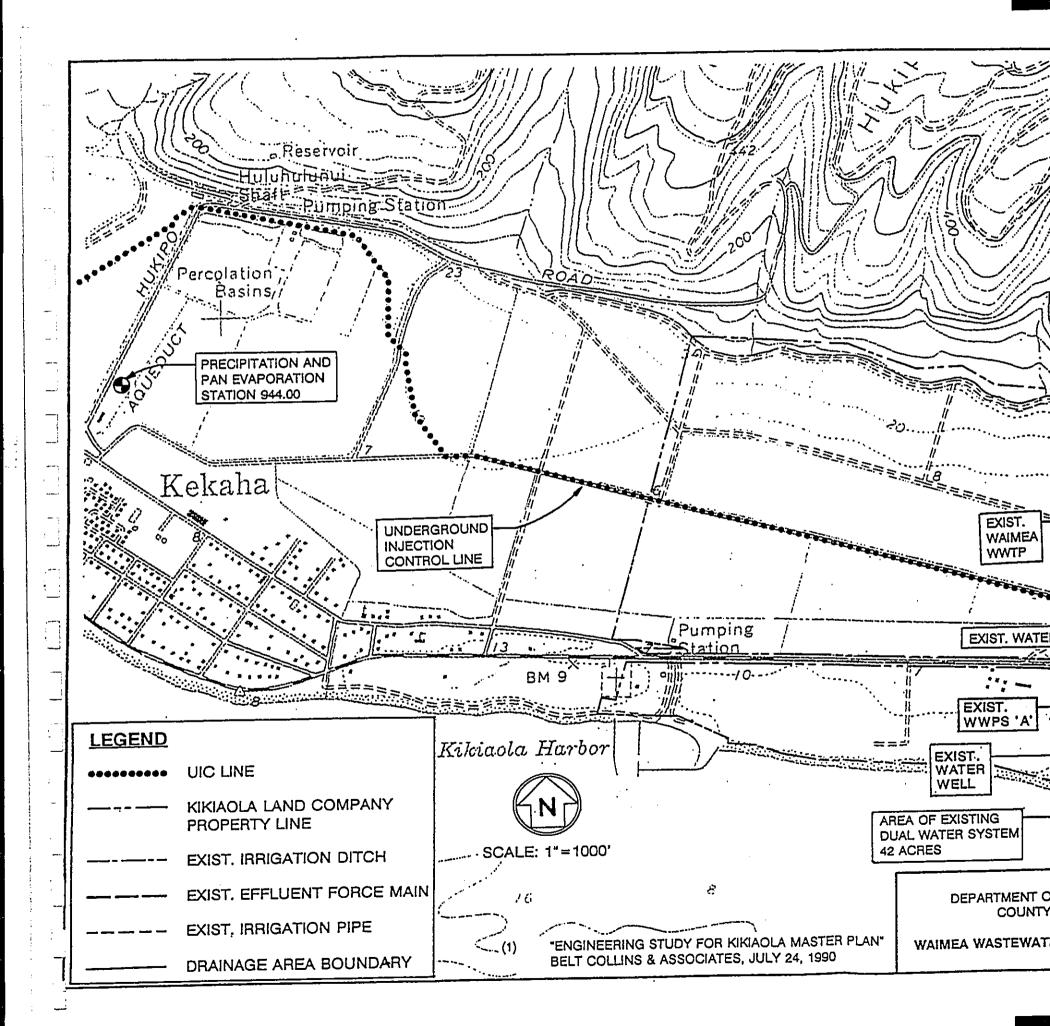
The County should file a UIC Application Permit with the State for construction of two injection wells, each with a capacity of 1.2 mgd, as soon as possible.

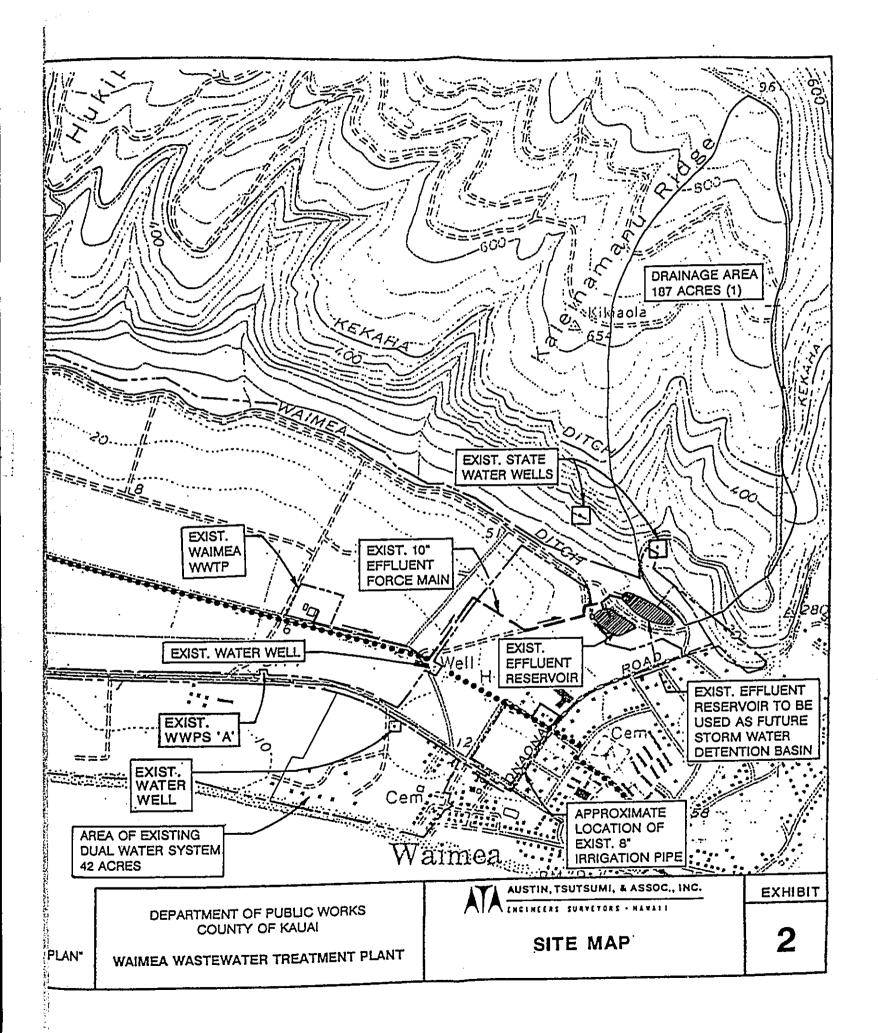


AUSTIN, TSUTSUMI & ASSOCIATES, INC.

EXHIBITS

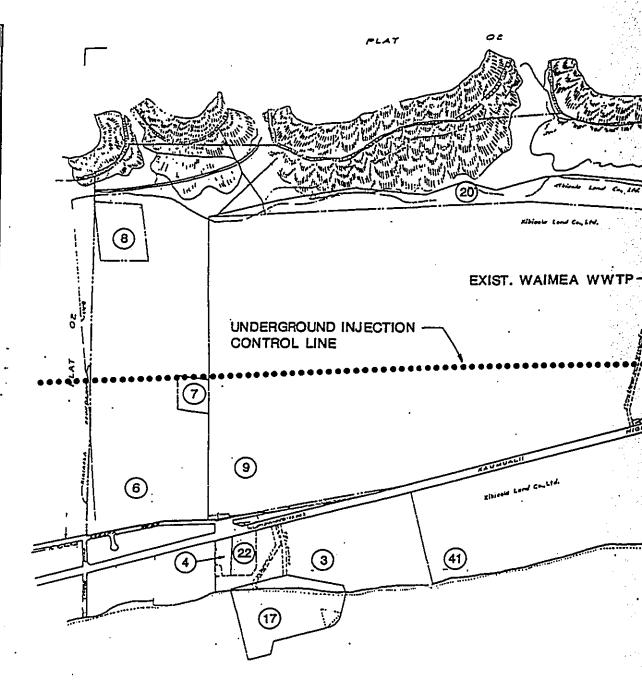






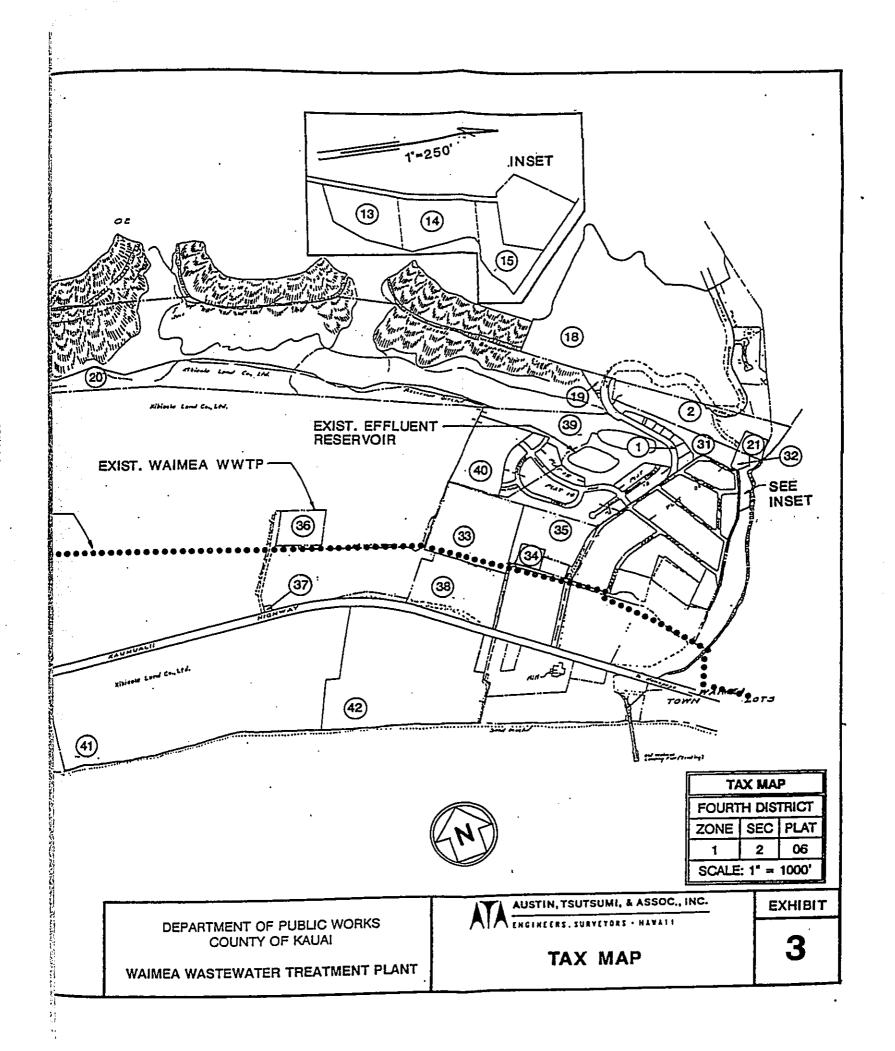
LOT NO.	LAND OWNER	LOT NO.	LAND OWNER
1	KIKIAOLA LAND CO.	21	STATE OF HAWAII
2	OTHER	22	KIKIAOLA LAND CO.
3	KIKIAOLA LAND CO.	31	KIKIAOLA LAND CO.
4	STATE OF HAWAII	32	KIKIAOLA LAND CO.
6	KNUDSEN	33	STATE OF HAWAII
7	KNUDSEN	34	KIKIAOLA LAND CO.
8	KNUDSEN	35	STATE OF HAWAII
9	KIKIAOLA LAND CO.	36	COUNTY OF KAUAI
13	OTHER	37	COUNTY OF KAUAI
14	KIKIAOLA LAND CO.	38	STATE OF HAWAII
15	KIKAOLA LAND CO.	39	KIKIAOLA LAND CO.
17	STATE OF HAWAII	40	OTHER
18	STATE OF HAWAII	41	KIKIAOLA LAND CO.
19	KNUDSEN	42	KIKIAOLA LAND CO.
20	KIKIAOLA LAND CO.		

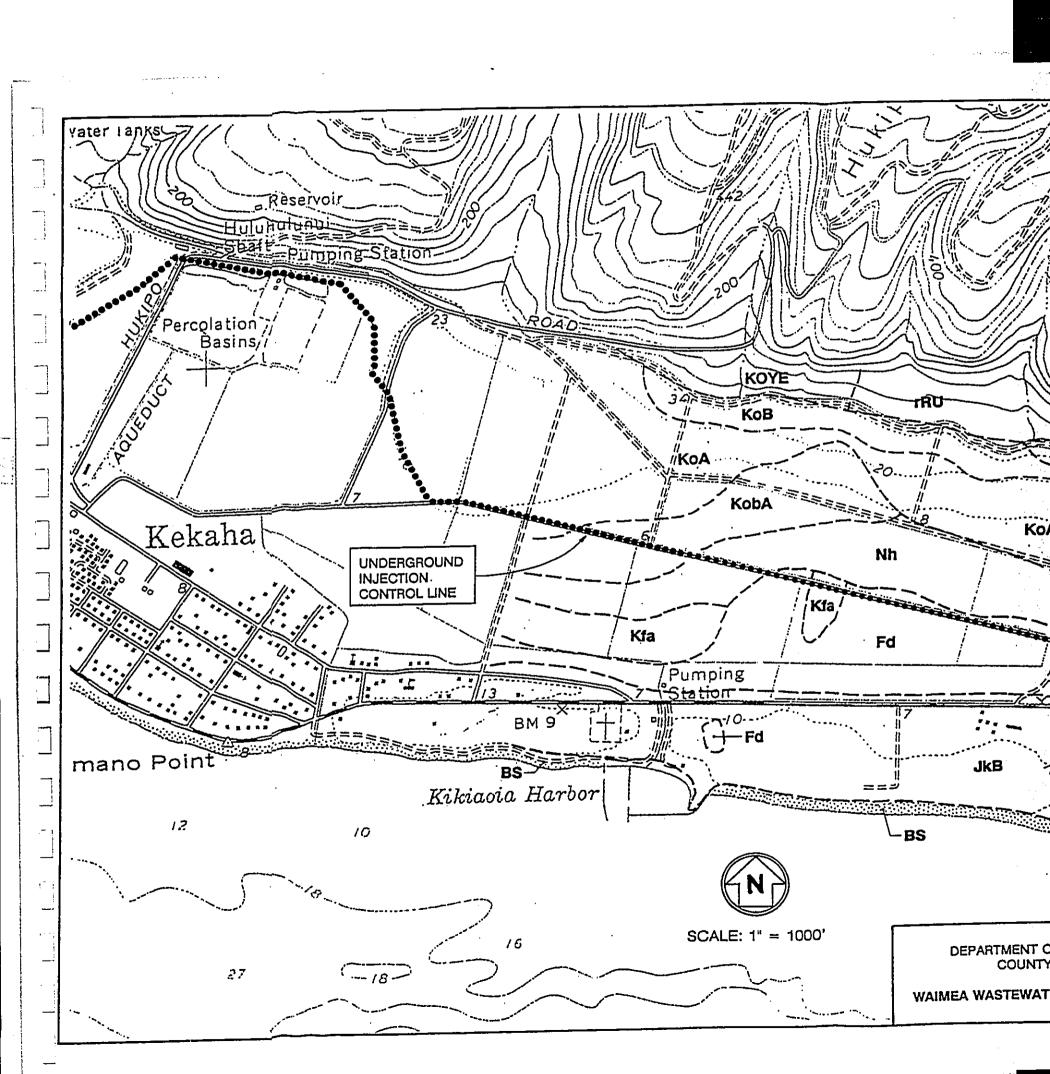
NOTE: Land owned by Augustus Knudsen is leased to Kekaha Sugar Co. Ltd.

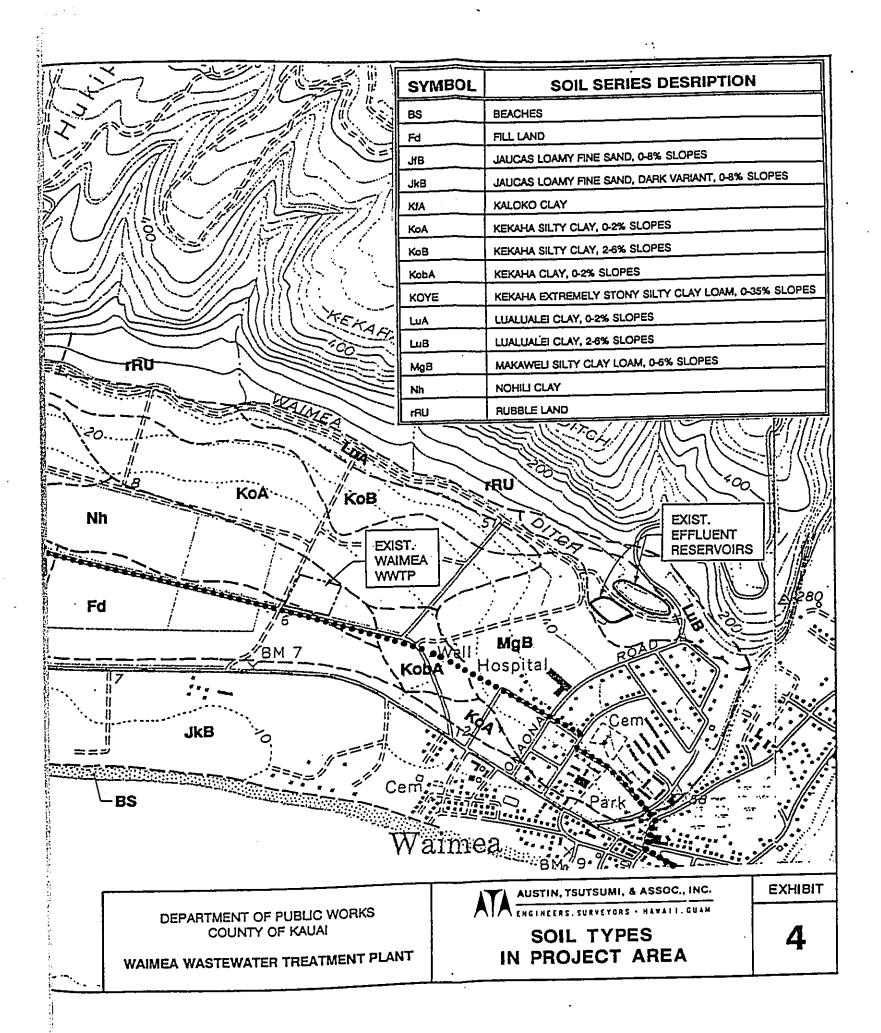


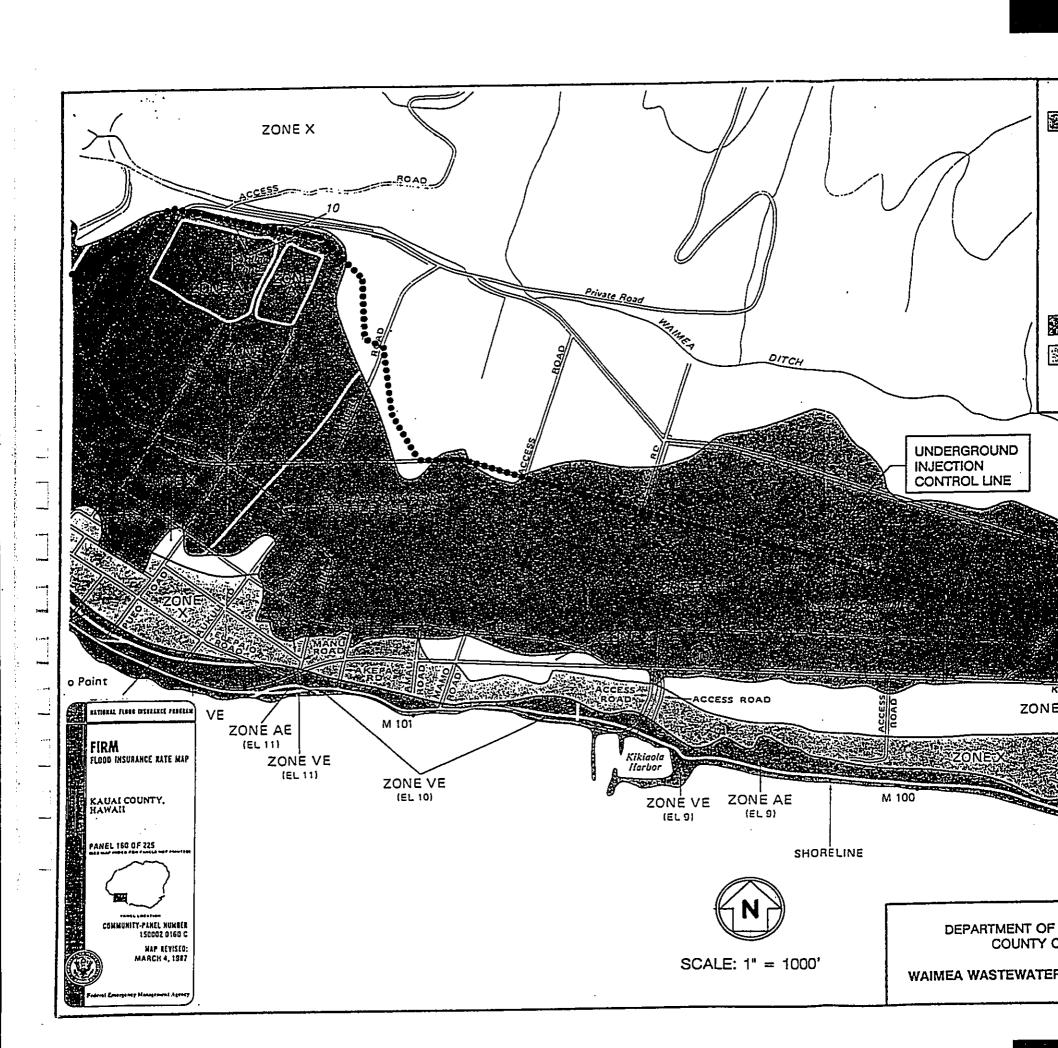
DEPARTMENT OF COUNTY OF

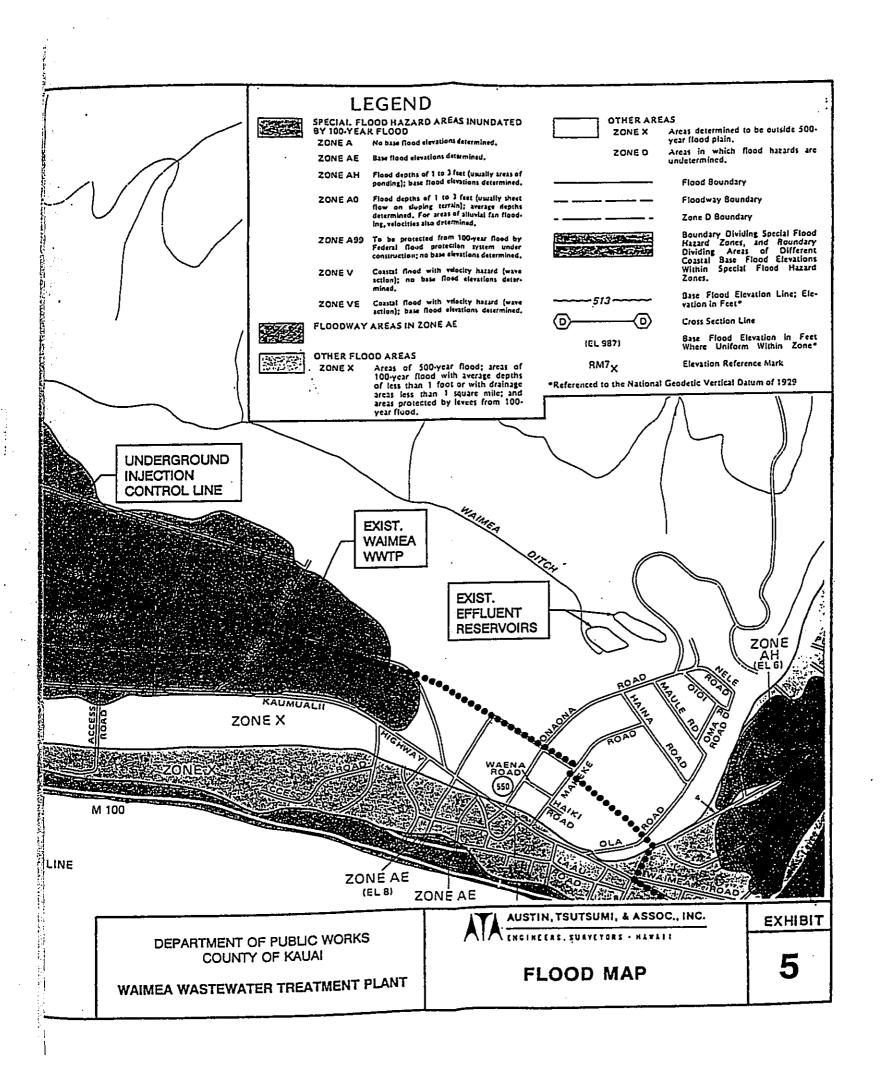
WAIMEA WASTEWATER

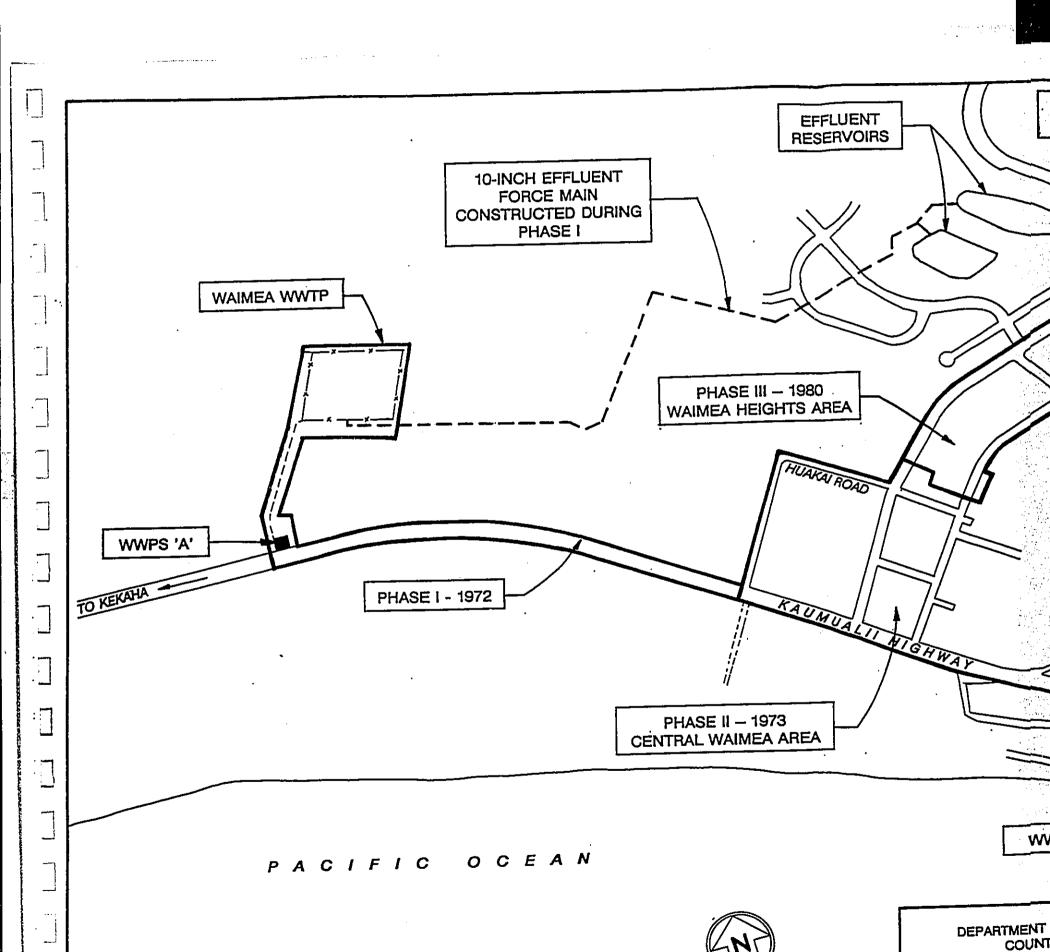






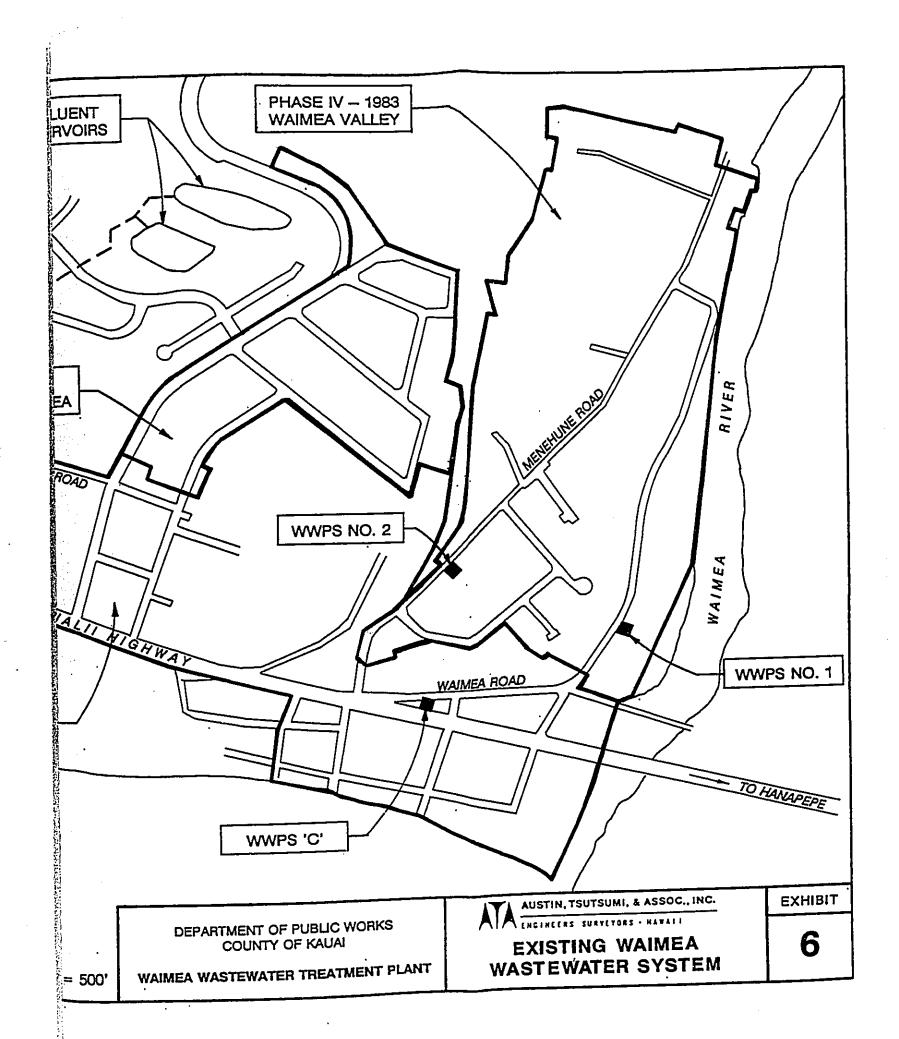


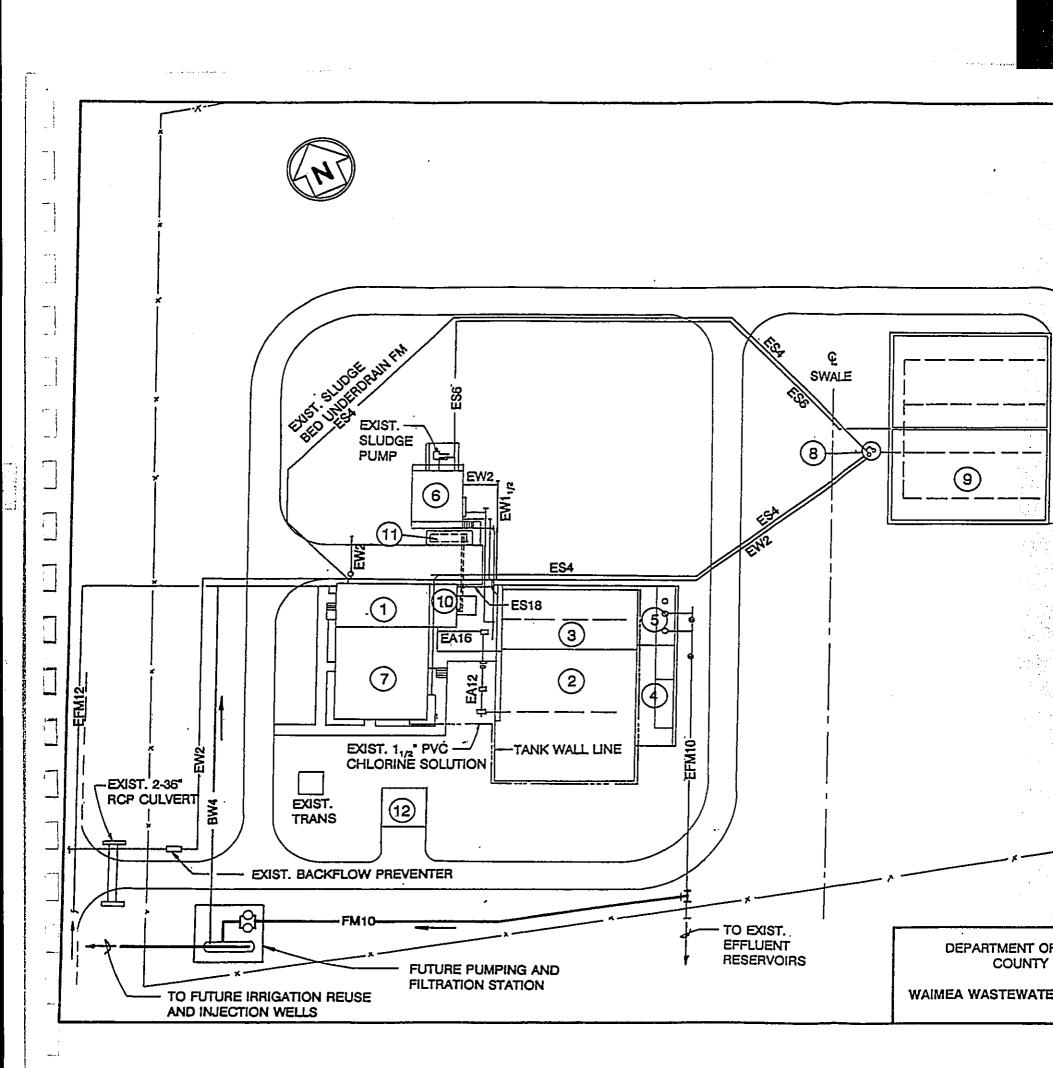


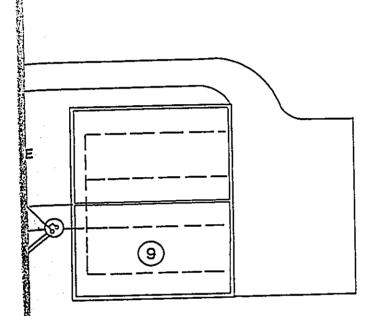


WAIMEA WASTEWA

SCALE: 1" = 500'







SC	CHEDULE OF EXISTING STRUCTURES
NO.	DESCRIPTION
1	COMMINUTING, DEGRITTING BASIN
2	AERATION TANKS
3	FINAL SETTLING TANKS
4	CHLORINE CONTACT TANK
5	EFFLUENT PUMP BASIN
6	AERATED SLUDGE HOLDING TANK
7	CONTROL BUILDING
8	SLUDGE BED UNDERDRAIN PUMP
9	SLUDGE DRYING BEDS
10	GENERATOR ROOM
11	UNDERGROUND FUEL TANK
12	EQUIP. AND MAINTENANCE BLDG

- CHAIN LINK FENCE AND PLANT BOUNDARY

SCALE: 1" = 40"

DEPARTMENT OF PUBLIC WORKS COUNTY OF KAUAI

WAIMEA WASTEWATER TREATMENT PLANT

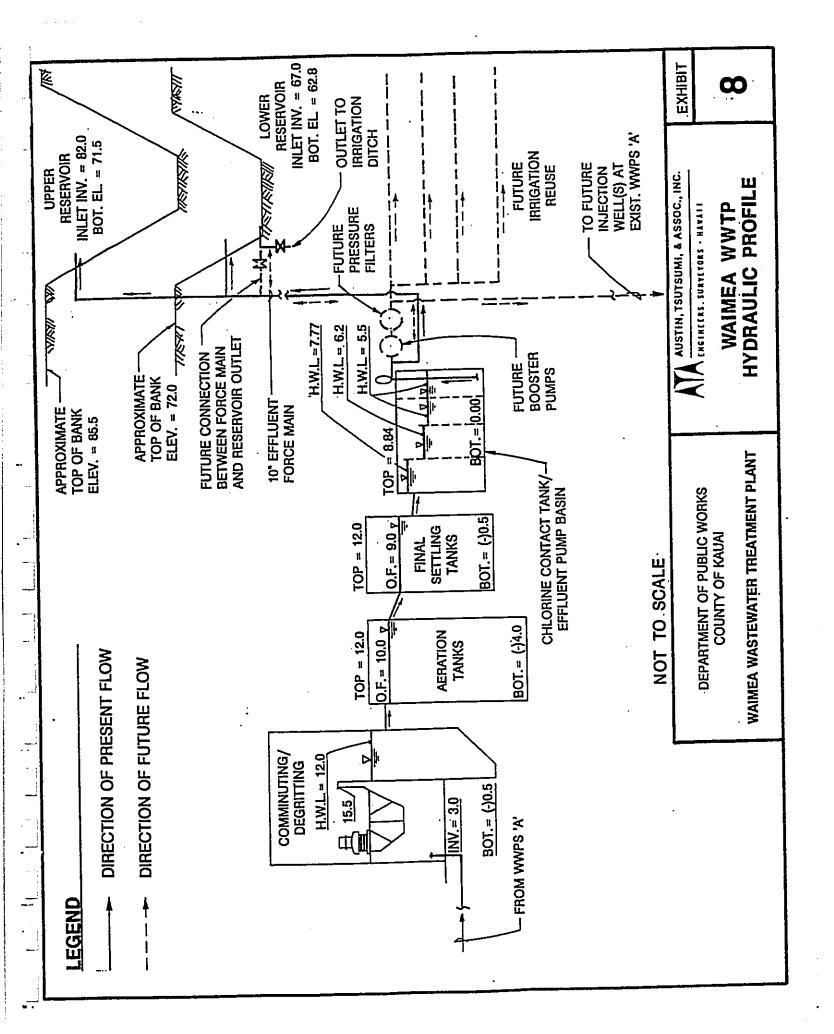
AUSTIN, TSUTSUMI, & ASSOC., INC.

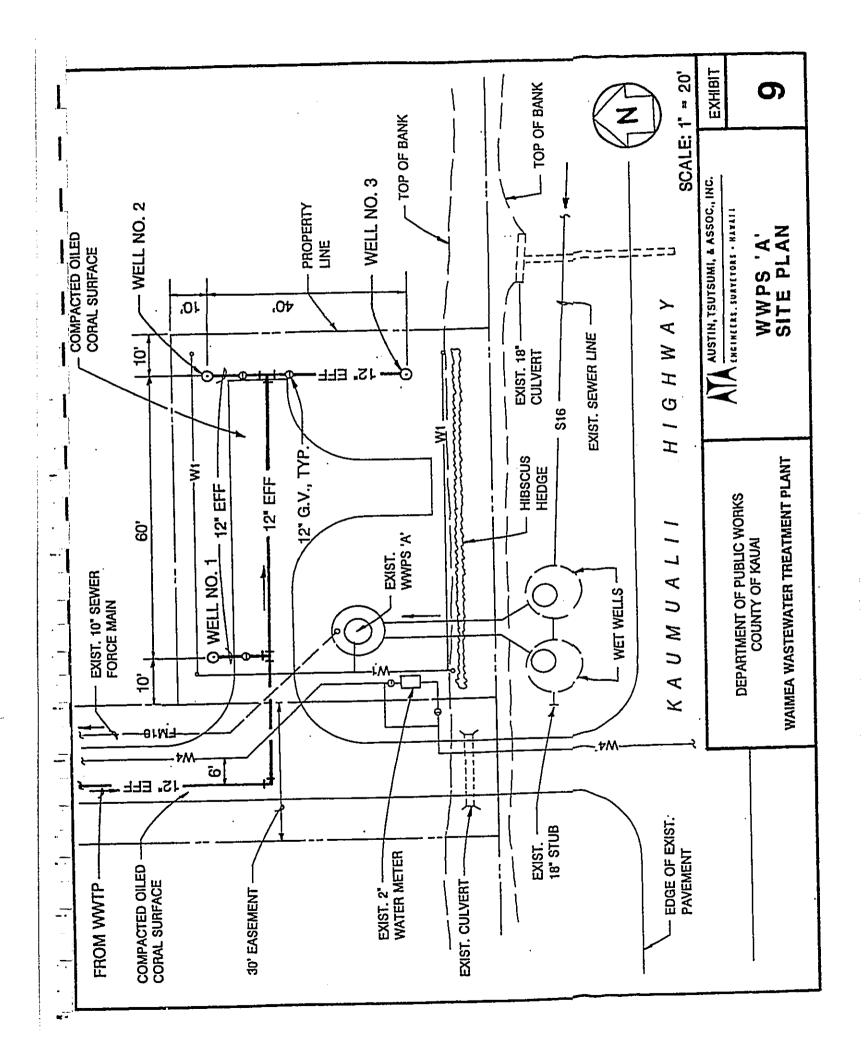
ENGINEERS SURVEYORS - HAVALL

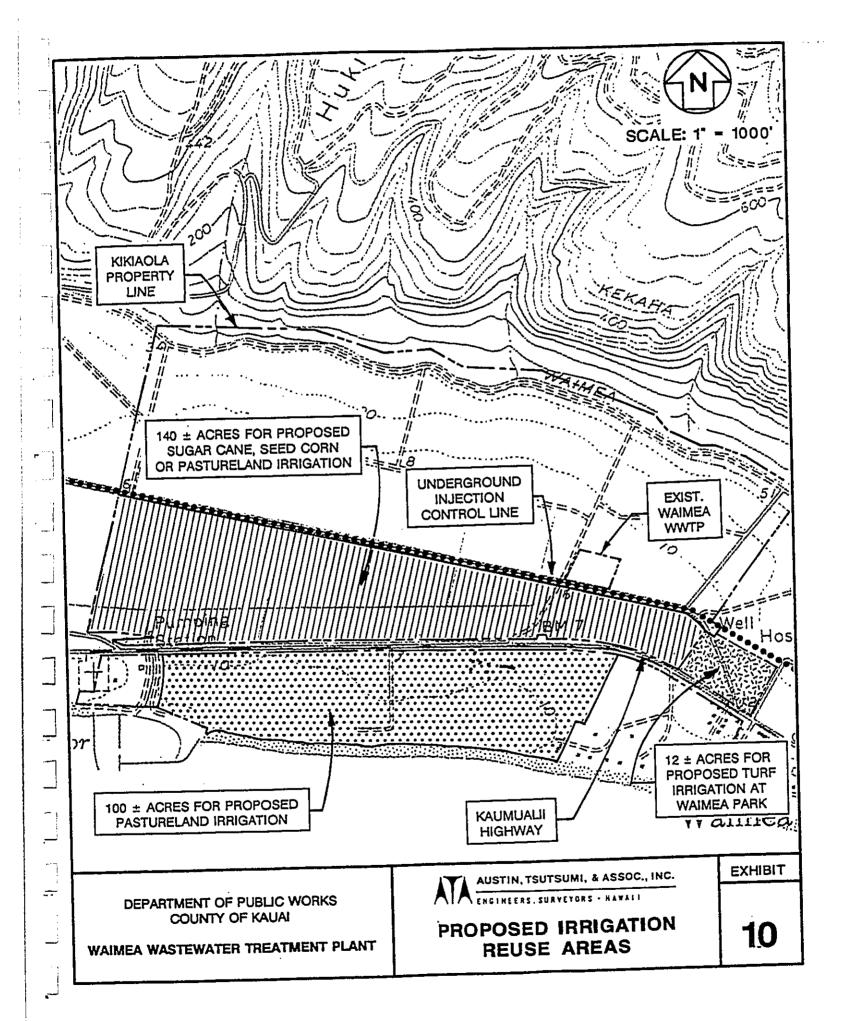
WAIMEA WWTP

EXHIBIT

7







APPENDICES

APPENDIX A

"WASTE WATER EFFLUENT DISPOSAL BY INJECTION WELLS", BY MINK & YUEN, INC. DATED AUGUST 1993

WASTEWATER EFFLUENT DISPOSAL BY INJECTION WELLS KIKIAOLA, KAUAI, HAWAII

Prepared by

Mink & Yuen, Incorporated

100 North Beretania Street, Suite 303

Honolulu, Hawaii 96817

Prepared for

Austin, Tsutsumi & Associates, Incorporated

501 Sumner Street, Suite 521

Honolulu, Hawaii 96817

August, 1993

TABLE OF CONTENTS

		PAGE
ı.	INTRODUCTION	1
II.	GENERAL GEOLOGY OF THE MANA-KEKAHA PLAN	1
III.	THE GROUNDWATER ENVIRONMENT	4
IV.	INJECTION HYDRAULICS	5
v.	BUOYANCY GRADIENT	7
VI.	RADIUS OF THE VERTICAL CYLINDRICAL SLUG	7
VII.	UPGRADIENT MOVEMENT OF INJECTANT	8
VIII.	SEEPAGE OF WASTEWATER INTO THE CAPROCK	12
īX.	FATE OF NUTRIENTS	13
x.	SUMMARY	14
xI.	RECOMMENDATION	15
xrı.	DATA SURVEY	17
XIII.	REFERENCES	18
	•	
	<u>FIGURES</u>	
FIG. 1	MAP OF REGION	
FIG. 2	LITHOLOGY OF KEKAHA HILL WELL	
FIG. 3	LITHOLOGIC LOGS OF WELLS IN THE MANA PLAIN	
FIG. 4	LOCATION OF WELLS	
FIG. 5	SECTION THROUGH STP TO COAST	
FIG. 6	HYDROGEOLOGICAL ENVIRONMENT FOR LEAKY	
	AQUIFER ANALYSIS	

Introduction

The hydrogeological data base for the coastal plain lying between Waimea and Polihale State Park in western Kauai is sparse, even though numerous wells have been drilled. This report utilizes the existing data base and extrapolates beyond it with conceptual models consistent with known patterns of hydrogeological conditions in analogous situations. The analyses that follow are keyed to the State Department of Health requirement that injection is not allowed where the groundwater has a concentration of 10,000 mg/l total dissolved solids (TDS) or less.

For the analyses in this report, the proposed maximum injection rate of 1.2 mgd is used.

General Geology of the Mana-Kekaha Plain

The waste water treatment plant (WWTP) and the sites where injection wells would be feasible are located in the eastern part of the coastal plain as it narrows between Kekaha and Waimea. The plain consists of a sequence of

sedimentary strata resting on the basement rock of Napali basalt. The sedimentary column, also called the caprock, is approximately 270 feet deep at the WWTP and 600 feet thick at the coast. Two miles to the west at well 5842-01 by the Kekaha Sugar Mill the caprock is 400 feet deep. Figure 2 is a lithology log of this well. Figure 1 is a map of the region showing the general surface geology and well locations.

The caprock sediments as a whole are poorly permeable and act as a confining layer on the Napali aquifer. Most of the strata are dominated by clay, but a few horizons of permeable coral and sand are sandwiched between the clays. A typical geological column in the vicinity of the WWTP starts with a layer of sand and coral reaching to about 60 feet below sea level where it rests on clay. Another coral layer about 20 feet thick lies between 110 and 125 feet below sea level, and another about 15 feet thick is sandwiched between clays from about 205 to 220 feet below sea level. The final stratum in the sedimentary column is a clay overlying the weathered zone of the Napali formation. Figure 3 illustrates all of the lithologic logs available for wells in the Mana Plain, and Figure 4, modified from DOWALD Report R 53, shows locations of the wells.

The probable distribution of the coral and clay layers between Kekaha and Waimea is illustrated in Figure 5. This

diagram is a cross-section of the subsurface geology along a line drawn perpendicular to the coast and the cliffs at the inner margin of the plain while passing through the WWTP. Noted on the figure are TDS concentrations encountered in wells when they were first drilled in 1929-1930, before continuous pumping started. The TDS concentrations are converted from chloride concentrations using the chloride to TDS ratio in sea water. The estimated half sea water isoconcentration at 17,500 mg/l TDS is also indicated.

Coral layers are much more permeable than clays and may be able to accept injected fluid. However, only the highest stratum starting at ground level is thick enough to accommodate a high rate of injection. The other two coralline layers are probably too thin to take 1.2 mgd.

The top sand and coral stratum probably could accommodate an injection rate of 1.2 mgd, but this formation is open to the sea at and for some distance off the coast. Unless mixing of sea water with effluent seepage along the coast were rapid, the effluent nutrients might provide an opportunity for marine blooms. The cesspools and septic tanks emplaced in this layer already add nutrient-rich effluent to the ambient groundwater.

The injection alternative having the greatest chance of success with fewest constraints is by way of deep wells

penetrating into brackish to saline water below the fresh water core of the basal lens in the Napali formation. The caprock/Napali contact slopes at an angle of about 8 degrees near Kekaha. To avoid the 10,000 TDS isoconcentration, wells will have to be more than 500 feet deep.

The Groundwater Environment

In Figure 5 the theoretical half sea water concentration (17,500 mg/l TDS) is plotted from head data. This concentration contour is the middle of the transition zone, and its depth below sea level is calculated by multiplying the head by the Ghyben-Herzberg constant, 40. Salinity above the midpoint decreases symmetrically. A fresh water core lies above the transition zone.

The thickness of the upper limb of the transition zone depends on the groundwater flux and the mode of discharge of the lens. In a lens unprotected by caprock, the transition is thin if flux is high because discharge takes place as a line sink along the coast. In a thick lens confined by caprock, the transition zone would be wider for the same rate of groundwater flow because discharge is hampered by the low permeability of the caprock/basalt interface. The upper limb of the transition zone in the vicinity of Kikiaola is probably on the order of 100 feet thick. In this limb the

10,000 mg/l TDS contour lies.

To avoid encountering groundwater containing less than 10,000 mg/l TDS, the injection wells will have to placed seaward of the WWTP somewhere in the vicinity of Highway 50 (Kaumuali Road) or further seaward. At the highway the caprock/Napali contact is about 400 feet below sea level and TDS of the ambient groundwater is at least 13,000 mg/l (the original concentration at the Kekaha Mill well at the time of drilling in 1930) and more likely 22,000 mg/l (an analysis in 1972). To handle 1.2 mgd, the injection well will have to penetrate 200 feet into the Napali aquifer. Thus, at the highway an injection well will have to be 600 feet deep to be reliable. Further seaward the required depth will increase. At the coast, for example, a well would have to be 800 feet deep.

Injection Hydraulics

The waste water injected into the Napali aquifer will have a lower density than the ambient groundwater, and if the density difference is significant, the waste water will rise as a plume around the well until it encounters the caprock. A portion will travel upgradient along the interface to a stagnation point, and the bulk will move downgradient as a slug in the ambient flow field. Eventually the wastewater

will seep into the caprock, driven by a positive potential in the aquifer relative to the potential in the caprock. The area of seepage depends on the permeability of the caprock interface and the injection rate.

If the difference in density between the ambient groundwater and the injected fluid is very small, the injectant will not rise but, instead, will form a plume in the ambient flow field. The difference in density for the Kikiaola injection, however, is likely to be significant enough to result in vertical movement of the injectant.

Assuming the injection takes place in the lower limb of the transition zone where the TDS concentration ranges from 17,500 mg/l to sea water, the average density of the ambient groundwater will be 1.0188. The density of the waste water is taken as 1.0000 because it is very nearly fresh water.

To predict where the injectant will travel and if it might impact ambient groundwater having less than 10,000 mg/l TDS, four behavioral characteristics of the injectant need to be examined: 1) the buoyancy gradient, 2) radius of the buoyant column, 3) upgradient movement of the slug along the caprock interface, and 4) rate of discharge into the caprock and area over which discharge takes place. Once in the caprock, the injectant will move seaward to eventually discharge at the sea bottom.

Buoyancy Gradient

The buoyancy gradient is expressed as:

 ${g(a) - g(c)}/{g(a)}$

in which g(a) is density of the ambient groundwater, taken as 1.0188, and g(c) is density of the waste water, 1.0000. The density difference is .0188; if the ambient groundwater were sea water, the difference would be .025. Derivations of the buoyancy gradient are given in Mink and Lau (1980); Burnham, Larson and Cooper (1977); and Wheatcraft (1979).

The gradient is high, and therefore the upward velocity of flow is rapid. Assuming the vertical hydraulic conductivity (k) in the Napali basalt is 200 ft/day, equal to about one tenth the horizontal conductivity, and effective porosity (n) is .05 (these parameters are commonly used in numerical modeling), the velocity is:

v = .0188 (k/n) = 75 ft/day.

Manifestly the vertical plume will quickly establish itself all the way from the bottom of the screen to the caprock interface because the vertical velocity is much greater than the ambient flow field velocity of 5 to 10 ft/day.

Radius of the Vertical Cylindrical Slug

In their analysis of the fate of injected waste water at

the Kahului, Maui WWTP, Burnaham, et al (1977) derived an expression for the radius of the cylindrical slug along the screen of the injection well. The average radius, r(av), is written as:

 \cdot

 $r(av) = (2/3) (Q/\pi kg)^{1/2}$

in which Q is injection rate, k is vertical hydraulic conductivity, and g is the buoyancy gradient. For an injection rate of 1.2 mgd over a screen length of 200 feet, the average radius of the slug will be 78 feet. The maximum radius at the top of the screen will be 117 feet.

The caprock, because of its low permeability, can't accept all of the injectant over this small a radius. The injectant will move upgradient to a stagnation point where the potential of the slug equals that of the ambient flow, and downgradient along the caprock/basalt interface.

Upgradient Movement of Injectant

The methods employed to predict injected effluent behavior are simple and straightforward because the absence of reliable caprock and basalt aquifer parameters does not justify use of numerical modeling. The vertical distribution of salinity is based on information from pumping wells, and the position of the transition zone is inferred from heads measured at wells. The depth to the midpoint of the

transition zone is equal to 40 times the head. The position of the fresh water core, transition zone and sea water is illustrated in Figure 5.

The injectant enters the aquifer with a higher potential than the ambient groundwater and therefore will travel as a slug upgradient until the potential of the two fluids are equal. At the edges of the slug hydrodynamic dispersion will occur, but by and large the slug will retain its identity. The stagnation radius, or the distance the slug will travel upgradient before stopping, is:

$r(stag) = Q/(2\pi bki)$

in which Q is the injection rate, b is the thickness of the slug, k is horizontal hydraulic conductivity, and i is gradient of the ambient flow field.

This formula assumes the aquifer is homogeneous and isotropic, confined and infinite in extent. In spite of these limitations, it is a reasonable approximation of behavior of the injectant after it rises into the basal lens. The EPA software program WHPA utilizes this equation. Hydrodynamic dispersion is not accounted for.

For Q of 1.2 mgd, b of 100 feet, k at 2000 ft/day, and i of 1/5000, r(stag) is 638 feet. The b value is a compromise, chosen as one half the screen length; the k and i values are typical of basal aquifers in Hawaii.

Under the stated assumptions the maximum width of the plume can be calculated as:

w = Q/kbi.

The plume will expand to this width several miles downgradient of the well. However, the caprock, beneath which the plume travels, behaves as a leaky confining layer into which the injectant is able to seep. If the caprock contact were impermeable, the plume would continue downgradient until it encountered openings where the sedimentary blanket tails off.

Employing the same values for Q, k, b and i as above, the width of the plume at the injection site will be 2000 feet, or 1000 feet on either side of the well. Two wells located next to each other but receiving 0.6 mgd each would generate a similar plume width. Injection wells capable of accepting a combined rate of 1.2 mgd do not have to be distant from each other because neither the plume width nor the stagnation radius will impact other wells.

For a well located at Highway 50, the slug of injected waste water would travel upgradient to about where the 50 percent sea water concentration encounters the caprock. Under these circumstances, groundwater with less than 10,000 mg/l would not be impacted. A well between the WWTP and the road, however, would encroach into the upper limb of the transition

zone and might affect water having less than 10,000 mg/l TDS.

Note that if the average injection rate was to be as high as

0.6 mgd, the stagnation radius would be only 316 feet.

The landward extent of the injection slug will not affect any operational wells driven into the basalt aquifer. The nearest Kauai County Water Department wells are 5840-01, about 0.9 miles upgradient of the proposed injection site, and 5840-02, about 0.75 miles upgradient (see Figure 1). The upgradient reach of the injection plume will be less than 1000 feet and will be restricted to a depth of about 300 feet below sea level. The depth of wells 5840-01 and 5840-02 are 52 and 18 feet below sea level, respectively. According to the Department of Water Supply, the next well to be drilled will be located between Waimea and Kekaha at the cliff line at the inner margin of the coastal plain. The well will be at least one mile upgradient of the injection site.

Well 5840-01 is the principal well used for municipal water supply. It is equipped with a 500 gpm pump. At this rate of pumpage the downgradient stagnation point is 380 feet. This distance added to the upgradient stagnation distance of 638 feet for the proposed injection well will allow a separation of about 3000 feet between the envelope of flow to 5840-01 and the upgradient reach of the injection plume.

Seepage of Waste Water into the Caprock

The permeability of the clay at the base of the caprock is quite low, probably less than 1 ft/day and perhaps on the order of 0.1 ft/day. The seepage rate per unit area from the Napali aquifer into the caprock is correspondingly small. Yet the caprock is the ultimate destination of the basal water.

An analysis employing leaky aquifer concepts provides an estimate of the area of caprock required to accept the injected waste water. Figure 6 illustrates the hydrogeological environment on which the analysis is based. The expression:

$$q(x)/q(0) = \exp \{-x/(kbC)^{\frac{1}{2}}\}$$

gives the ratio of flow remaining at a distance downgradient of the section where flow is q(0). In the expression, q(x) is flow at a distance x from the section q(0), k is horizontal hydraulic conductivity, b is depth of flow, and C = b'/k' in which b' is the thickness of the caprock stratum receiving seepage and k' is hydraulic conductivity of this stratum.

For k (Napali) = 2000 ft/day, b = 100 feet, b' = 50 feet and k' = 0.1 ft/day,

$$q(x)/q(0) = .9048$$

which states that approximately 10 percent of the flow in the Napali seeps into the caprock over a distance of 1000 feet.

Over a linear distance of 10,000 feet, 63 percent seeps into the caprock. For k' = 1 ft/day, the respective seepage values would be 27 percent and 96 percent.

A large caprock/Napali interface area is required to discharge the basal lens and its slug of injected waste water, but most of the area of seepage will be downgradient of the injection well. Over the upgradient distance (638 feet) less than 10 percent of the effluent will enter the caprock; the remainder moves down the interface slope.

Fate of Nutrients

Nutrients and other dissolved matter in the injectant will eventually dissipate into the sedimentary caprock, and then ultimately discharge into the sea at a considerable distance from the coast and deep below sea level. The process of dispersion in the saline water of the caprock and distributed seepage from the caprock into sea water will reduce the concentration of dissolved matter at the caprocksea water interface.

The injected effluent will be prevented from mixing in coastal waters by the thick wedge of caprock. The caprock extends as a low permeability blanket for an unknown distance off shore. It is not possible to state just where the injectant will finally mix with water in the open sea, but

unquestionably it will be a considerable distance off shore and at a depth of hundreds of feet.

The sea floor slopes gently from 0 to 60 feet depth over a distance of 3000 feet from the coast, indicating that the caprock wedge extends at least over this distance. It then slopes more steeply, from depth 60 to depth 300 feet over the next 3000 feet, and more steeply over the next 1000 feet from depth 300 to depth 600 feet. The steepening slope traces the descent of the front of the caprock wedge. The depth of 600 feet lies 7000 feet off shore. Whether the injectant seepas into the caprock or remains in the basalt aquifer, its emergence in the sea floor will take place no closer than one half mile from the coast.

Summary

Groundwater in the Napali basalt aquifer inland of the WWTP contains less than 10,000 mg/l TDS and therefore is ineligible for injection wells. The 10,000 mg/l TDS isoconcentration intersects the caprock about midway between the WWTP and Highway 50. Between here and the coast all groundwater has more than 10,000 mg/l TDS.

The waste water effluent will have a density nearly that of fresh water while the ambient groundwater will range from half to full sea water salinity. At Highway 50 groundwater in

the Napali constitutes the lower half of the transition zone and has an average composition of 26,000 mg/l TDS and density of 1.0188. In an injection well located here, the difference in density between the waste water and the ground water will cause the injectant to rapidly rise as a cylindrical slug around the well screen. On reaching the caprock/Napali contact, a plume will move to a stagnation point about 640 feet upgradient, and the remainder will move downgradient along the contact. The upgradient slug will not interfere with groundwater containing less than 10,000 mg/l TDS.

Eventually the waste water injectant will seep into the caprock. A large surface area of the caprock/Napali interface is required to discharge the basal lens, including the injectant fluid. Most of the seepage into the caprock will take place downgradient of Highway 50 and will have no impact at the shore line where the caprock is 600 feet thick. Groundwater seeping into the caprock has no opportunity to rise to discharge at an open coast.

Recommendation

Locate two injection wells at Highway 50, or between the Highway and the coast, wherever a site is available. If each well is rated at a maximum of 1.2 mgd, with an average that is up to half of this rate (i.e., 0.6 mgd), they can be placed within 50 feet of each other.

Wells at Highway 50 will have to be 600 feet deep. They will be cased and grouted throughout the 400 feet thickness of the caprock. The 200 feet section in the Napali basalt will either be screened or open, depending upon the nature of the formations encountered. The diameter of the casing and screen will depend on the volume rate of injection. At an injection rate of 1.2 mgd for each well, a 12 or 14 inch diameter casing will be required.

Data Summary Mana Coastal Plain Well's with a Data Record

Well	Grd. El(ft)	Napali <u>El(ft)</u>	Depth <u>El(ft)</u>	C1(0) mg/l	C1(P) mg/l	h(ft)
5842-01 0044-13 0044-14 0045-03 0145-22 0145-23 0145-24 0146-04	9 8 8 10 9 10 10 9	-394 -153 -155 -181 -149 -154 -152 -235 -160	-481 -206 -237 -252 -236 -244 -265 -352 -243	7130 81 139 135 94 93 114 498	11,800 200-800 400-900 130-180 310-650 250-700	8.3 10.5 10.3 9.5 10.4 10.4

Column Explanation

Well: State number.

Grd.El(ft): Elevation of ground surface above sea level.

Napali El(ft): Elevation of caprock/Napali contact.

Depth El(ft): Elevation bottom of well.

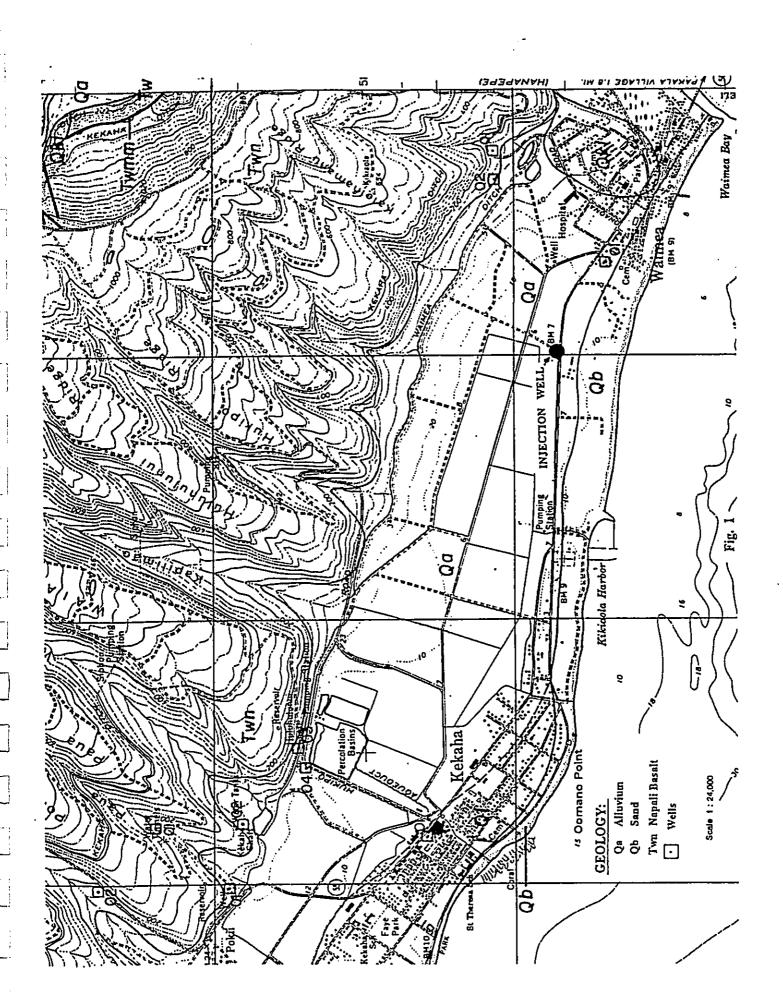
Depth El(ft): Initial chloride during drilling, before pumping.

Cl(0) mg/l: Chloride during pumping.

h(ft): Average head, feet above sea level.

References

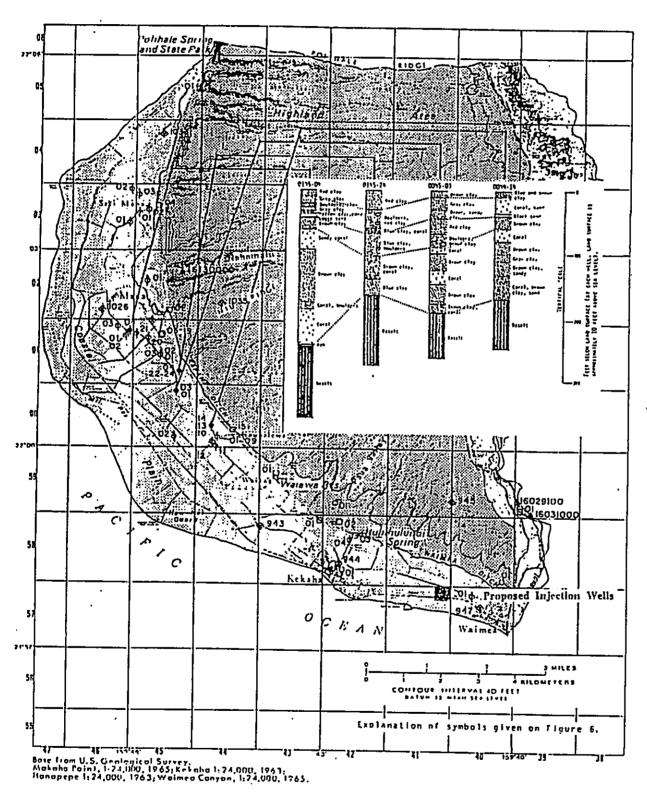
- 1. Burnham, W.L., Larson, S.P., and Cooper, H.H., 1977, Distribution of Injected Wastewater in the Saline Lava Aquifer, Wailuku-Kahului Wastewater Treatment Facility, Kahului, Maui, Hawaii: U.S. Geological Survey OFR 77-469.
- Burt, R.J., 1979, Availability of Groundwater for Irrigation on the Kekaha-Mana Coastal Plain, Island of Kauai, Hawaii: State of Hawaii Dept. Land and Natural Resources, Report R53.
- 3. Mink, J.F., and Lau, L.S., 1980, Hawaiian Groundwater Geology and Hydrology and Early Mathematical Models: Univ. Hawaii Water Resources Research Center, Tech. Mem. 62.
- 4. Macdonald, G.A., Davis, D.A., and Cox, D.C., 1960, Geology and Ground-Water Resources of the Island of Kauai, Hawaii: State of Hawaii Division Hydrography, Bulletin 13.



5842-01 (27) KEKAHA IIILL .								
DEPTH		ELEV (m)						
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Δ 38]	GRAVEL	-25	Cl = 11,800					
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78	IROWN GLAY	-66						
. 92	1/1/1/1/	-82						
100		-92						
	CAYE							
			•					
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195	7/2///	-185						
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•	CLAY .							
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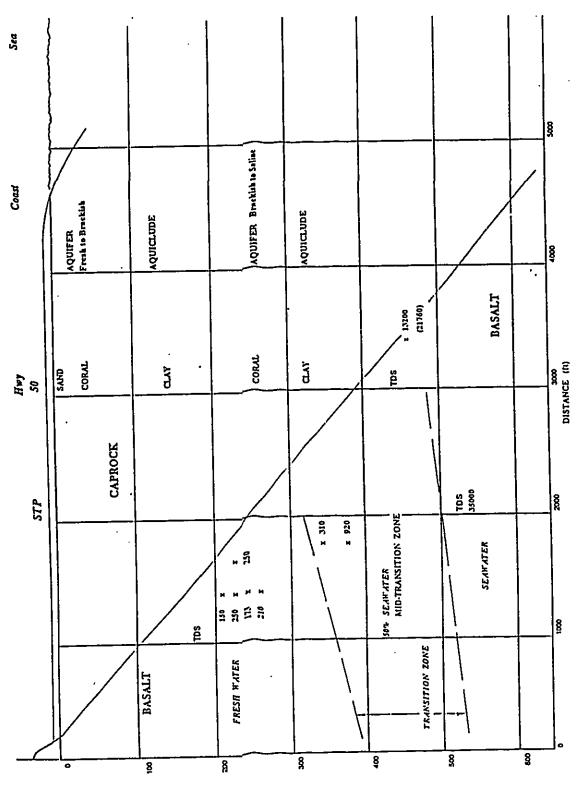
Fig. 2

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Schematic Sections of Representative Wells Showing the Top of the Basalt and Coralline Layers. Ifrom State of Hawaii DOWALD Report R-53]

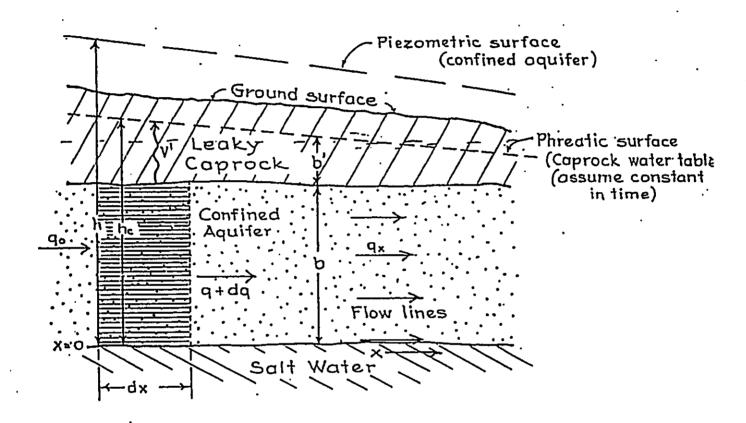
Fig. 4



KIKIAOLA SECTION CLIFF LINE THROUGH STP to COAST

Fig. 5

Steady flow, two dimensional, flow through aquifer horizontal; flow through caprock vertical. Aquifer and caprock isotropic, infinite extent:



NOTE: Assume sharp interface, lowest fresh water flow line undeformable, thus salt water equivalent to impermeable boundary.

APPENDIX B

EXCERPTS FROM U.S. SOILS CONSERVATION SERVICE'S "SOIL SURVEY OF ISLANDS OF KAUAI, OAHU, MAUI, MOLOKAI AND LANAI, STATE OF HAWAII" AUGUST 1972 These soils are used for water supply and wildlife habitat. The natural vegetation consists of clubmoss, lapalapa, ohelo, ohia, sedges, false staghornfern, and

Amalu peaty silty clay, 3 to 20 percent slopes (rAMD).—This soil is on high ridges and mountaintops. Included in mapping were small areas of Honomanu and Olokui soils and of steep gulches.

In a representative profile an organic layer of black peat, about 8 inches thick, overlies a layer of gray massive clay about 8 inches thick. The substratum is soft

sive clay about 8 inches thick. The substratum is soft, weathered basic igneous rock capped by a horizontal ironstone sheet 1/8 to 1 inch thick. The soil is extremely

acid above the ironstone layer.

Permeability is restricted by the ironstone sheet, which is impermeable except for cracks. Runoff is very slow, and the erosion hazard is no more than slight. Roots

penetrate to a depth of 8 to 15 inches in places. Representative profile: Island of Maui, lat. 20°48'46" N. and long. 156°13'44" W.

and long. 156°13'44" W.

Ol—8 inches to 0, black (5YR 2/1) peat; massive; soft, nonsticky and nonplastic; abundant medium and coarse
roots; extremely acid; abrupt, wavy boundary. 5 to
15 inches thick.

A2g—0 to 8 inches, gray (10YR 5/1) clay; massive; firm,
sticky, plastic and weakly smeary; abundant roots;
many, fine and medium, tubular porces; common darkgray (10YR 4/1) organic stains; extremely acid;
abrupt, smooth boundary. 4 to 15 inches thick.

B2irm—S to S½ inches, dark reddish-brown (5YR 2/2) horizontal, laminar ironstone sheet that has a surface
that appears to be troweled; thin coating of
yellowish-red (5YR 4/6) soft material on upper surface. ½ to 1 inch thick.

C—S¼ to 60 inches ÷, very dark gray (10YR 3/1) saprolite
that has light-gray (10YR 7/1) and yellowish-red
(5YR 5/6) colors in and adjacent to cracks; breaks
down to smeary silt loam; saprolite has some original rock structure; soft plinthite in cracks or coatings around rock cores; few, hard, discontinuous
ironstone sheets, up to 1 inch thick, oriented horizontally and vertically. Many feet thick.

The depth to the ironstone sheet ranges from 8 to 15 inches

The depth to the ironstone sheet ranges from 8 to 15 inches below the base of the O1 horizon. The A2g horizon ranges from 10NR to 5N in hue, from 2 to 5 in value, and from 1 to 2 in chroma. In places a black mucky layer, 1 to 2 inches 2 in chroma between the A2g and B2irm horizons.

This soil is used for water supply and wildlife habitat. (Capability classification VIIw, nonirrigated; woodland

Amalu-Olokui association, 3 to 20 percent slopes (rAOD).—This association consists of Amalu peaty silty clay, 3 to 20 percent slopes, and Olokui silty clay loam, 3 to 30 percent slopes. It is on intermediate uplands in the eastern part of the island of Molokai. Amalu soils make up about 60 percent of the association, and Olokui soils about 40 percent. Amalu soils occupy the depressions and the wetter sites. Included in mapping were small areas of Kahanui soils and many small, very steep gulches.

This association is used for water supply and wildlife habitat. (Amalu part is in capability classification VIIw, nonirrigated; woodland group 16. Olokui part is in capability classification VIIIw, nonirrigated; woodland

group 16)

Badland

Badland consists of steep or very steep, nearly barren land, ordinarily not stony. The soil-forming material is generally soft or hard saprolite. The annual rainfall amounts to 22 to 60 inches. Elevations range from nearly

amounts to 22 to 60 inches. Elevations range from nearly sea level to about 3,000 feet. This land type is mapped on the island of Kauai and, in addition, as part of soil complexes on Lanai, Molokai, and Oahu.

Badland (Bl).—This land type occurs on the island of Kauai. It is steep to very steep and nearly barren. Runoff is very rapid, and geological erosion is active. Included in mapping were areas of Kalapa, Lihue, and Makaweli soils.

This land type is used for water supply and wildlife habitat. Ironwood trees have been planted in small areas. (Capability classification VIIIe, nonirrigated)

Badland-Mahana complex (BM).—This complex occurs on the western side of the island of Kauai. Badland makes up about 60 percent of the acreage; Mahana silt loam, 20 to 35 percent slopes, makes up about 40 percent. Elevations range from 1,500 to 3,000 feet. The annual rainfall amounts to 30 to 45 inches. Slopes are steep to very steep. very steep.

very steep.

Most of the Badland part of this complex is barren, but some areas have been planted to ironwood, silk-oak, and eucalyptus. The Mahana part is used for pasture and woodland. (Badland part is in capability classification VIIIe, nonirrigated. Mahana part is in capability classification VIe, nonirrigated; pasture group 6; woodland group 5) group 5)

Beaches (BS) occur as sandy, gravelly, or cobbly areas on all the islands in the survey area. They are washed and rewashed by ocean waves. The beaches consist mainly of light-colored sands derived from coral and seashells. A few of the beaches, however, are dark colored because their sands are from basalt and andesite.

Beaches have no value for farming. Where accessible and free of cobblestones and stones, they are highly suitable for recreational uses and resort development. (Capability classification VIIIw, nonirrigated)

Blown-out Land

Blown-out land (BW) occurs mainly on the windswept northern plateau of the island of Lanai. The slope ranges from 0 to 15 percent, but included in mapping were areas adjacent to gulches and hummocks, where the slope is as much as 40 percent. Elevations range from 1,500 to 1,700 feet. The annual rainfall amounts to 15 to 25 inches. Strong trade winds are common. Most areas are barren and are eroded to the compact subsoil or to soft, weathered rock. The subsoil material is similar to that of Kanepuu and Lahaina soils. As much as 10 percent of the area has hummocks or small dunes that are partly of the area has hummocks or small dunes that are partly stabilized by dallisgrass, molassesgrass, bermudagrass, and ilima. Runoff is rapid, and the erosion hazard is severe.

The main management requirement on this land type is the provision of vegetative cover to check further loss of soil material. Test plantings of pineapple have indi-

Ewa stony silty clay, 6 to 12 percent slopes (EwC).-This soil has a profile like that of Ewa silty clay loam, 3 to 6 percent slopes, except for the texture of the surface layer. Surface stones interfere with tillage but do not make intertilled crops impracticable. Runoff is slow to medium, and the erosion hazard is slight to moderate.
Included in mapping were small, gently sloping areas.
This soil is used for pasture. (Capability classification IIIe if irrigated, IVe if nonirrigated; sugarcane

group 1; pasture group 2)

Fill Land

This land type consists of areas filled with material from dredging, excavation from adjacent uplands, garbage, and bagasse and slurry from sugar mills. The areas are on the islands of Kauai, Maui, and Oahu.

Fill land (Fd).—This land type consists mostly of areas filled with bagasse and slurry from sugar mills. A few areas are filled with material from dredging and from soil excavations. Generally, these materials are dumped and spread over marshes, low-lying areas along the coastal flats, coral sand, coral limestone, or areas shallow to bedrock.

This land type is used mostly for the production of sugarcane. (Not in a capability classification)

Fill land, mixed (Fl).—This land type occurs mostly near Pearl Harbor and in Honolulu, adjacent to the ocean. It consists of areas filled with material dredged from the ocean or hauled from nearby areas, garbage, and general material from other sources. Included in mapping were a few areas that have been excavated.

This land type is used for urban development including airports, housing areas, and industrial facilities. (Not in a capability classification)

Gullied Land

Gullied land (GI) occurs on the island of Molokai. It is so cut by recent gullies that it is nonarable and the soil profile has been largely destroyed. Erosion is very active, and the soil is bare in many places. Kiawe, ilima, uhaloa, and piligrass provide some protection. Elevations range from nearly sea level to 1,200 feet. The annual rainfall amounts to 20 to 25 inches. This land type is geographically associated with Pamoa, Waikapu, Hoolehua, and

Waihuna soils.
Gullied land occurs in the heads of drainageways and on alluvial terraces along the streams. Near the upper margins of the drainageways, almost vertical-sided gullies have cut back into the undisturbed soil areas, leaving remnants of deep soil between gullies. Farther down the slopes, these little spurs are also eroded to varying degrees; at still lower elevations, stones and bedrock are left in the gullies. Slopes on these gulches range from 25 to 70 percent. Where this land type occurs on alluvial terraces, as in the Mahana area of Molokai (fig. 3), there are small tillable areas between gullies. The slope is 3 to 15 percent, and some stones are scattered on the surface. The areas are small and unimportant for cultivation.

This land type is used for pasture. (Capability classification VIIe, nonirrigated)

Haiku Series

This series consists of well-drained soils on uplands on the island of Maui. These soils developed in material weathered from basic igneous rock. They are gently to moderately sloping. Elevations range from nearly sea level to 1,200 feet. The annual rainfall amounts to 50



Figure 3.—Gullied land on alluvial terraces. This land type is in the Mahana area on the island of Molokai. 414-129-72-3

Permeability is slow to moderately slow. Runoff is medium, and the erosion hazard is moderate. The available water capacity is about 1.4 inches per foot of soil. Roots penetrate to a depth of 15 to 25 inches or to the plow depth.

Representative profile: Island of Kauai, lat. 22°07'32.9"

N. and long. 157°13'03" W.

Ap1—0 to 6 inches, dark-brown (7.5TR 3/4) silty clay loam, brown (7.5TR 4/4) when dry; cloddy, breaking to moderate, fine and very fine, subangular blocky structure; hard, firm, sticky and plastic; abundant medium and fine roots and plentiful very fine roots; very strongly acid; abrupt, wavy boundary. 6 to 8 inches thick

turn and fine roots and plentiful very fine roots; very strongly acid; abrupt, wavy boundary. 6 to 8 inches thick.

Ap2—6 to 15 inches, mixture of yellowish-red (5YR 4/6) silty clay loam, strong brown (7.5YR 5/6) when dry; massive; slightly hard, friable, sticky and plastic; and yellowish-red (5YR 4/6) silty clay, reddish brown (5YR 4/4) when dry; strong, very fine, subangular blocky structure; hard, firm, sticky and plastic; few medium roots and plentiful fine and very fine roots; common fine pores; very strongly acid; abrupt, wavy boundary. 7 to 10 inches thick.

B21t—15 to 27 inches, dark reddish-brown (5YR 3/4) silty clay, reddish brown (5YR 4/4) when dry; strong, fine and very fine, subangular blocky structure; very hard, firm, sticky and plastic; very few fine and very fine roots; common very fine pores; very compact in place; many moderately thick clay films on ped faces; very strongly acid; clear, wavy boundary.

5 to 12 inches thick.

B22t—27 to 38 inches, dark-brown (7.5YR 3/2) silty clay, yellowish red (5YR 3/6) in pores, dark brown (7.5YR 4/4) when dry; strong, fine and very fine, subangular blocky structure; very hard, firm, sticky and plastic; very few fine and very fine roots; few medium pores and many very fine pores; compact in place; many moderately thick clay films on ped faces and in pores; few pebbles; very strongly acid; clear, wavy boundary. 9 to 11 inches thick.

B23t—38 to 57 inches, dark-brown (7.5YR 3/3) light silty clay, dark brown (7.5YR 4/4) in pores, dark brown (7.5YR 4/4) when dry; strong, fine and very fine, subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; few medium, fine, and very fine roots; many very fine pores; patchy, moderately thick clay films on ped faces; continuous in pores; few pebbles; extremely acid; clear, wavy boundary. 15 to 22 inches thick.

B24t—57 to 61 inches, dark reddish-brown (5YR 3/4) silty clay loam, reddish brown (5YR 4/4) when dry; moderately thick clay films on ped faces; patchy, moderately thick clay films on p

The A horizon ranges from 5YR to 10YR in hue. In places the texture of the A horizon is clay loam. The B horizon ranges from 2.5YR to 7.5YR in hue, from 3 to 4 in value, and from 2 to 6 in chroma. The depth to the very compact B21t ranges from 15 to 25 inches.

This soil is used for sugarcane, pasture, pineapple, orchards, and truck crops. (Capability classification IIIe, irrigated or nonirrigated; sugarcane group 1; pineapple

group 6; pasture group 6; woodland group 6)

Ioleau silty clay loam, 2 to 6 percent slopes (108).— This soil has a profile like that of Ioleau silty clay loam, 6 to 12 percent slopes, except that it is 10 to 20 inches deeper to the compact layer. Runoff is slow, and the crosion because it is a slow, and the crosion because it is a slow. sion hazard is slight. Roots penetrate to a depth of 25 to 40 inches.

This soil is used for sugarcane, pasture, pineapple, orchards, and truck crops. (Capability classification He, irrigated or nonirrigated; sugarcane group 1; pineapple group 5; pasture group 6; woodland group 6)

Toleau silty clay loam, 12 to 20 percent slopes, eroded

(IoD2).—This soil is similar to Ioleau silty clay loam, 6 to 12 percent slopes, except that it is moderately steep and part of the surface layer has been removed by erosion. Runoss is rapid, and the erosion hazard is moderate to

This soil is used for sugarcane, pineapple, and pasture. (Capability classification IVe, irrigated or non-

irrigated; sugarcane group 1; pineapple group 6; pasture group 6; woodland group 6)

Ioleau silty clay loam, 20 to 35 percent slopes, eroded (1052).—This soil is similar to Ioleau silty clay loam, 6 to 12 percent slopes, except that it is steep and most of the surface layer has been removed by erosion. Runoff is

rapid, and the erosion hazard is severe.

This soil is used for pasture, woodland, sugarcane, pineapple, and water supply. (Capability classification VIe, nonirrigated; pasture group 6; woodland group 6)

Jaucas Series

This series consists of excessively drained, calcareous soils that occur as narrow strips on coastal plains, adjacent to the ocean. These soils occur on all the islands of this survey area. They developed in wind- and water-deposited sand from coral and seashells. They are nearly level to strongly sloping. Elevations range from sea level to 100 feet; but locally on West Molokai, the elevation is as high as 650 feet. The annual rainfall amounts to 10 to 40 inches. The mean annual soil temperature is 75° F. Jaucas soils are geographically associated with

75° F. Jaucas soils are geographically associated with Pulehu, Mokuleia, Kaloko, and Lualualei soils.

In this survey area a dark variant of the Jaucas series was mapped. This soil, Jaucas loamy fine sand, dark variant, 0 to 8 percent slopes, is described in alphabetical order, along with other mapping units of this series.

These soils are used for pasture, sugarcane, truck crops, alfalfa, recreational areas, wildlife habitat, and urban development. The natural vegetation consists of kiawe, kon haole, bristly foxtail, bermudagrass, fingergrass, and Australian saltbush.

Jaucas sand, 0 to 15 percent slopes (IoC).—The slope range of this soil is 0 to 15 percent, but in most places the slope does not exceed 7 percent. Included in mapping were narrow strips of Beaches and areas of Pulehu,

Mokuleia, and Keāau soils.

In a representative profile the soil is single grain, pale brown to very pale brown, sandy, and more than 60 inches deep. In many places the surface layer is dark brown as a result of accumulation of organic matter and alluvium. The soil is neutral to moderately alkaline

throughout the profile.

Permeability is rapid, and runoff is very slow to slow. The linzard of water erosion is slight, but wind erosion is a severe hazard where vegetation has been removed. The available water capacity is 0.5 to 1.0 inch per foot of soil. In places roots penetrate to a depth of 5 feet or more. Workability is slightly difficult because the soil is loose and lacks stability for use of equipment.

Representative profile: Island of Molokai, lat. 21°05'38" N. and long. 157°13'03" W.

C1—0 to 13 inches, pale-brown (10YR 6/3) sand, light yellowish brown (10YR 6/4) when dry; single grain; loose, nonsticky and nonplastic; plentiful roots; violent effervescence with dilute hydrochloric acid; neutral; gradual, wavy boundary. 3 to 15 inches thick.

C2—13 to 22 inches, light yellowish-brown (10YR 6/4) sand, very pale brown (10YR 7/4) when dry; single grain; loose, nonsticky and nonplastic; few roots; violent effervescence with dilute hydrochloric neid; mildly alkaline; gradual, wavy boundary. 6 to 30 inches thick.

C3—22 to 60 inches, very pale brown (10YR 7/4) sand; single grain; loose, nonsticky and nonplastic; violent effervescence with dilute hydrochloric acid; neutral.

The texture of the surface layer is dominantly sand, but in a few places it is fine sand or loamy sand. In some places there is an A horizon, a few inches thick, that is darkened by organic matter and alluvium. The profile is 10YR in hue. It ranges from 6 to 7 in value, and, in chroma, from 2 to 4 when moist. Pebble-size fragments of coral and seashell are common in the profile. common in the profile.

This soil is used for pasture, sugarcane, truck crops, and urban development. (Capability classification IVs if irrigated, Vie if nonirrigated; sugarcane group 1; pas-

Jaucas sand, saline, 0 to 12 percent slopes (IcC).—This soil occurs near the ocean in areas where the water table is near the surface and salts have accumulated. It is somewhat poorly drained in depressions but excessively drained on knolls. In the depressions there is normally a layer of silty alluvial material flocculated by the high concentration of soluble salts. The water table is normally suithing a darth of 30 inches

within a depth of 30 inches.

This soil is used for pasture, wildlife habitat, and urban development. Vegetation on the salty soil in the depressive prodevelopment. Vegetation on the saity soil in the depressions consists of salt-tolerant plants. Kiawe grows profusely on the better drained soils on knolls. (Capability classification VIIs, nonirrigated; pasture group 1)

Jaucas loamy fine sand, 0 to 8 percent slopes (MB).—
This soil occurs on old beaches and on windblown sand densits in the western and southern parts of Kanai Transitions.

deposits in the western and southern parts of Kauai. It has a profile like that of Jaucas sand, 0 to 15 percent

has a profile like that of Jaucas sand, 0 to 15 percent slopes, except for the texture of the surface layer.

This soil is used for pasture, recreational areas, wild-life habitat, sugarcane, and alfalfa. (Capability classification IVs if irrigated, VIe if nonirrigated; sugarcane group 1; pasture group 1)

Jaucas loamy fine sand, dark variant, 0 to 8 percent slopes (JkB).—This soil occurs on Kauai near the town of Waimea. Unlike other soils of the Jaucas series, sand and coral sand are mixed throughout the profile. The basaltic sand gives this soil a dark-brown to black color. This soil is used for sugarcane, pasture, and homesites.

basaltic sand gives this soil a dark-brown to black color. This soil is used for sugarcane, pasture, and homesites. (Capability classification IVs if irrigated, VIe if non-irrigated; sugarcane group 1; pasture group 1)

Jaucas-Blown-out land complex (II).—This complex occurs as a long, nearly level to moderately sloping strip in the northwestern part of the island of Molokai. It is inland where strong prevailing winds have lifted and carried coral sand from sea level to elevations of about 650 feet. The Jaucas soil, which makes up 25 to 70 per-650 feet. The Jaucas soil, which makes up 25 to 70 percent of the acreage, occurs as small dunes. In many places it is mixed with fine material from Blown-out land, and the texture is loamy sand. Blown-out land consists of

an exposed compact subsoil and substratum similar to those of Molokai soils. Included in mapping were a few

limestone outcrops. This complex is used for pasture. Kinwe trees are scrubby and scattered because they cannot obtain moisture from the water table. Most of the forage consists of grasses that grow mainly during the rainy season. Much of the area is barren. Strong winds are prevalent, and wind and water erosion is active. (Capability classificution VIe, nonirrigated; pasture group 1)

Kaena Series

This series consists of very deep, poorly drained soils on alluvial fans and talus slopes on the islands of Oahu on alluvial fans and talus slopes on the islands of Oahu and Kauai. These soils developed in alluvium and colluvium from basic igneous material. They are gently sloping to steep and are commonly stony. Elevations range from 50 to 150 feet. The annual rainfall amounts to 30 to 45 inches, most of which occurs between November and April. The mean annual soil temperature is 74° F. Kaena soils are geographically associated with Honouliuli, Lualualei, and Waialua soils.

In this survey area brown variants of the Kaena series were mapped. These soils, Kaena clay, brown variant, 1 to 6 percent slopes, and Kaena clay, brown variant, 6 to 12 percent slopes, are described in alphabetical order, along with other mapping units of the series.

These soils are used for sugarcane, truck crops, pasture, and homesites. The natural vegetation consists of kiawe, klu, lantana, koa haole, and fingergrass.

kiawe, klu, lantana, koa haole, and fingergrass.

Kaena stony clay, 6 to 12 percent slopes (KoeC).—This soil occurs on alluvial fans. Included in mapping were small areas of clayey, dark reddish-brown soils that are moderately well drained to well drained.

moderately well drained to well drained.

In a representative profile the surface layer is very dark gray clay about 10 inches thick. The next layer, 36 to more than 48 inches thick, is dark-gray and dark grayish-brown clay that has prismatic structure. It is underlain by highly weathered gravel. The soil is very sticky and very plastic, and it is mottled. It is slightly acid to neutral. acid to neutral.

Permenbility is slow. Runoff is slow to medium, and the erosion hazard is slight to moderate. The available water capacity is about 1.4 inches per foot in the surface layer and about 1.7 inches per foot in the subsoil. Workability is difficult because of the narrow range of moisture content within which the soils can be cultivated. There are sufficient stones to hinder, but not prevent, cultivation. The shrink-swell potential is very high. In places

the soil is affected by seepage.

Representative profile: Island of Oahu, lat. 21°41′50″

N. and long. 157°59′08″ W.

Ap—0 to 10 inches, very dark gray (10YR 3/1), moist and dry, stony clay; strong, fine and medium, subangular blocky structure; extremely hard, very firm, very sticky and very plastic; abundant fine and medium roots; common, very fine, tubular and interstitial porcs; few coral fragments; angular stones; few highly weathered pebble-size basalt fragments; common, black, organic stains; common, fine, distinct, dark yellowish-brown mottles; slight effervescence with hydrogen peroxide; slight effervescence with hydrochloric acid; neutral; abrupt, smooth boundary. 8 to 12 inches thick. 8 to 12 inches thick.

strong brown, reddish brown, and yellowish red; massive; extremely hard, firm, very sticky and very plastic; plentiful roots; common very fine pores; strongly acid; gradual, smooth boundary. 17 to 21 inches thick.

inches thick.

Cig—i6 to 60 inches, grayish-brown (2.5Y 5/2) and dark-gray (5Y 4/1) clay, gray (5Y 5/1) when dry; massive; extremely hard, firm, very sticky and very plastic; few roots; few fine pores; neutral; gradual, smooth boundary. 12 to 15 inches thick.

C2g—60 to 70 inches, dark-gray (5Y 4/1), olive-gray (5Y 5/2), and yellowish-brown (10YR 5/6) clay; olive (5Y 5/3) with mottles of brownish yellow (10YR 6/6) when dry; massive; extremely hard, firm, very sticky and very plastic; few roots; few very fine pores; slight effervescence with hydrogen peroxide; neutral.

The A horizon ranges from 2 to 3 in value and from 1 to 3 in chroma. Mottles range from none to few. The B horizon ranges from neutral to 2.5Y and 5Y in hue, from 4 to 5 in value, and from 0 to 1 in chroma. Mottles range from components many mon to many.

This soil is used for irrigated sugarcane. (Capability classification IIIw if irrigated, IVw if nonirrigated; sugarcane group 3; pasture group 7; woodland group 4)

Kaloko Series

This series consists of poorly drained soils on coastal plains on the islands of Kauai and Oahu. These soils developed in alluvium derived from basic igneous rock; the alluvium has been deposited over marly lagoon deposits. The soils are nearly level. Elevations range from sea level to 20 feet. The annual rainfall amounts to 20 to 25 inches. The mean annual soil temperature is 73° F. Kaloko soils are geographically associated with Nohili soils on Kauai and with Keaau, Pearl Harbor, and Waialua soils on Oahu. and Waialua soils on Oahu.

and Waiaiua soils on Canu.

In this survey area a noncalcareous variant of the Kaloko series was mapped. This soil, Kaloko clay, noncalcareous variant, is described in alphabetical order, along with other mapping units of this series.

These soils are used for irrigated sugarcane and pasture. The natural vegetation consists of kiawe, klu, hereald grass and annuals.

bermudagrass, and annuals.

Kaloko clay (Klo).—This soil is nearly level and occurs on coastal plains. Included in the areas mapped on Oahu were small areas that consist mainly of coral fragments or marly material; areas of clayer, very poorly drained soils that are underlain by peat or muck; and small areas of dark reddish-brown, very deep, moderately well drained alluvial soils bermudagrass, and annuals.

drained alluvial soils.

In a representative profile the surface layer is darkbrown clay about 12 inches thick. The subsoil, about 3 inches thick, is dark reddish-brown and weak-red clay. Below this is mottled, white to light-gray, platy silty clay about 13 inches thick. This is underlain by dark greenish-gray and dark-gray massive silty clay. The soil is mildly alkaline to neutral throughout the profile.

Permeability is moderately slow to slow. Runoff is slow to very slow, and the erosion hazard is no more than slight. The available water capacity is about 1.6 inches per foot of soil. Roots penetrate to a depth of about 40 inches or to the water table in undrained areas. Workability is somewhat difficult.

Workability is somewhat difficult.

Representative profile: Island of Kanai, lat. 22°01'6.5" N. and long. 159°46'10.1" W.

Ap—0 to 12 inches, dark-brown (7.5YR 3/2) clay; common, fine, distinct, red mottles and yellowish-white specks; weak, fine, subangular blocky structure; very hard, firm, very sticky and very plastic; abundant roots; moderate reaction with hydrogen peroxide; violent reaction with hydrochloric acid; mildly alkaline; clear, smooth boundary. S to 15 inches thick.

B2—12 to 20 inches, dark reddish-brown (5YR 3/3) and weak-red (2.5YR 5/2) clay; many, fine, distinct mottles of brownish yellow (10YR 6/6), white (2.5Y S/2), and reddish yellow (5YR 6/6); moderate, fine, angular and subangular blocky structure; very hard, firm, very sticky and very plastic; plentiful roots; many fine pores; thin, patchy contings that look like illuviation cutans; slight reaction to bydrogen peroxide; violent reaction to hydrochloric acid; mildly alkaline; abrupt, smooth boundary. 7 to 11 inches thick.

oxide; violent renetion to hydrochloric acid; mildly alkaline; abrupt, smooth boundary. 7 to 11 inches thick.

IIC1g—20 to 29 inches, mottled white (2.57 8/1), reddish-brown (5YR 5/4), strong-brown (7.5XR 5/8), dark-brown (7.5XR 3/2), and gray (5Y 6/1) silty clay; rubbed color is light yellowish brown (2.5Y 6/3); weak, medium and thick plates; salt crystals between some plates; hard, firm, sticky and plastic; few roots; few fine and medium pores; violent reaction to hydrochloric acid; mildly alkaline; abrupt, smooth boundary. S to 11 inches thick.

IIC2sag—29 to 33 inches, layers of light-gray (N 6/0), gray (N 5/0), dark-gray (5Y 4/1), pink (7.5YR 8/4), grayish-brown (2.5Y 5/2), and reddish-brown (5YR 4/4) silty clay; rubbed color is olive gray (5Y 5/2); moderate, medium and thick plates; hard, friable, sticky and plastic; few roots; few fine pores; salt crystals make up about 50 percent of volume; neutral; abrupt, smooth boundary. 12 to 15 inches thick.

IIIC3g—33 to 43 inches, thickest plates are dark greenish-gray (5BG 4/1); silty clay; other plates are dark-gray (N 4/0), gray (5Y 5/1), and light-gray (5Y 6/1) silty clay; rubbed color is dark greenish gray (5BG 4/1); moderate, thin and thick plates; hard, friable, sticky and plastic; few roots; common fine and medium pores; moderate effervescence with hydrochloric acid; neutral; abrupt, smooth boundary.

9 to 11 inches thick.

IIIC4sag—43 to 60 inches, dark greenish-gray (5BG 4/1), and dark greenish-gray (5GY 7/1), greenish-gray (5GY 6/1), and dark greenish-gray (5GS 4/1) silty clay; rubbed color is greenish-gray (5GS 6/1); massive; friable, sticky; common salt crystals; moderate effervescence with hydrochloric acid; mildly alkaline.

The A horizon ranges from 5YR to 7.5YR in hue and from 1 to 2 in chroma. Mottles in the A horizon range from few to

The A horizon ranges from 5TR to 7.5TR in hue and from 1 to 2 in chroma. Mottles in the A horizon range from few to common. The B horizon ranges from 2.5TR to 10TR in hue and from 2 to 4 in chroma. The depth to the light-colored calcarcous C horizon ranges from 12 to 20 inches. The depth to the water table varies, because all the soils are artificially drained. Unless the soils are drained, the water table generally is at a depth of 12 to 20 inches.

This soil is used for irrigated sugarcane and pasture. (Capability classification IIIw if irrigated, Vw if non-irrigated; sugarcane group 3: pasture group 7)

Kaloko clay loam (Ki).—This soil is on the Mana plain on the island of Kauai. This soil has a profile like that

of Kaloko clay, except for the texture of the surface layer and horizontal lenses of sand in the underlying material. It is easier to work than that soil. Runoff is

wery slow, and there is no hazard of erosion.

This soil is used for sugarcane. (Capability classification IIIw if irrigated, Vw if nonirrigated; sugarcane group 3; pasture group 7)

Kaloko clay, noncalcareous variant (Kfb).—This soil occurs in slight depressions on the coastal plains on the island of Oahu. It is more acid and grayer than is typical

of the Kaloko series. It is underlain by noncalcareous material. The annual rainfall amounts to 40 to 60 inches. The surface layer is very dark gray clay. The subsoil is gray or grayish-brown prismatic clay. The substratum is massive clay and silty clay. This soil is slightly acid to next throughout. neutral throughout.

neutral throughout.

Included in mapping were small areas of very deep, well-drained alluvial soils in drainageways.

Permeability is slow. Runoff is ponded to very slow, and the erosion hazard is none to slight. The available enter correctly is 1.6 inches per foot of soil. In places and the erosion mazard is none to slight. The available water capacity is 1.6 inches per foot of soil. In places roots penetrate to a depth of 5 feet or more.

This soil is used for pasture and sugarcane. (Capability classification IIIw if irrigated, Vw if nonirrigated; sugarcane group 3; pasture group 7)

Kamaole Series

This series consists of well-drained soils on uplands on the island of Maui. These soils developed in volcanic ash. They are gently to moderately sloping. Elevations range from 1,500 to 2,300 feet. The annual rainfall amounts to 15 to 25 inches; most of it occurs in winter. The mean annual soil temperature is 69° F. Kamaole soils are geographically associated with Kaimu, Keawakapu, Kula, and Waiakoa soils.

These soils are used for pasture and wildlife habitat. The natural vegetation consists of bermudagrass, castorbean, false mallow, feather fingergrass, and kiawe.

Kamaole very stony silt loam, 3 to 15 percent slopes [KGKC].—This soil is on uplands. Included in mapping were small areas of Keawakapu and Kula soils. Also included were small areas where slopes have been removed. Outcrops of Aa lava are common.

In a representative profile the surface layer is dark-brown and dark reddish-brown silt loam and silty clay loam about S inches thick. The subsoil, about 12 inches thick, is dark reddish-brown silty clay that has subangular blocky structure. The substratum is fragmental Aa lava that has very little soil material in voids. The soil is medium acid and slightly acid in the surface layer and

mildly alkaline in the subsoil.

Permeability is moderate. Runoff is slow to medium, and the erosion hazard is slight to moderate. The available water capacity is about 1.2 inches per foot in the surface layer and subsoil. In places roots penetrate to a depth of 2 feet.

Representative profile: Island of Maui, lat. 20°45'00" N. and long. 156°21'44" W.

A11—0 to 2 inches, dark-brown (10YR 3/3) very stony silt loam, brown (10YR 4/3) when dry; moderate, thin and very thin, platy structure; soft, friable, slightly sticky and slightly plastic; abundant fine roots that have a tendency to mat on plate faces; common fine pores; few, fine, black concretions; 10 to 15 percent stones; slight effervescence with hydrogen peroxide; medium acid; abrupt, smooth boundary. 1 to 3 inches thick.

A12—2 to 8 inches, dark reddish-brown (5YR 3/2) silty clay

A12-2 to 8 inches, dark reddish-brown (5YR 3/2) silty clay to 8 inches, dark reddish-brown (5YR 3/2) silty clay loam, dark reddish gray (5YR 4/2) when dry; moderate, fine and very fine, subangular blocky structure; slightly hard, friable, sticky and plastic; plentiful fine roots; many fine and very fine pores; few, fine, black concretions; few moderately weathered pebbles; slight effervescence with hydrogen peroxide; slightly acid; gradual, wavy boundary. 4 to 7

inches thick.

B2—S to 20 inches, dark reddish-brown (5XR 3/2) cobbly silty clay, dark reddish brown (5XR 3/3) when dry; moderate, very fine and fine, subangular blocky structure; hard, firm, very sticky and very plastic; few roots; many fine pores; few, fine, black concretions; thin, patchy clay films on peds; few sand-size aggregates that are more resistant than the matrix; 10 to 20 percent weathered gravel and cobblestones; strong effervescence with hydrogen peroxide; mildly alkaline; clear, wavy boundary. 10 to 14 inches thick.

IIC—20 inches, fragmental An lava that contains a little soil material in voids.

The depth to fragmental Aa lava ranges from 16 to 24 inches. The A horizon ranges from 5YR to 10YR in hue, from 2 to 3 in value when moist and 3 to 4 when dry, and from 2 to 3 in chroma when moist and 2 to 4 when dry. The texture is silt loam or silty clay loam. The B horizon ranges from 5YR to 7.5YR in hue and from 2 to 3 in value when moist. The texture is silty clay loam or silty clay.

This soil is used for pasture and wildlife habitat. (Capability classification VIs, nonirrigated; pas-

ture group 3)

Kamaole extremely stony silt loam, 3 to 15 percent slopes (KGIC).—This soil is similar to Kamaole very stony silt loam, 3 to 15 percent slopes, except that stones cover 3 to 15 percent of the surface. Included in mapping were

small areas of rock outcrop.

This soil is used for pasture and wildlife habitat. (Capability classification VIs, nonirrigated; pas-

ture group 3)

Kaneohe Series

This series consists of well-drained soils on terraces and alluvial fans on the windward side of Oahu. These soils developed in alluvium and colluvium derived from basic igneous rock. In a few places they developed in volcanic ash and in material weathered from cinders. The soils are gently sloping to very steep. Elevations range from 100 to 1,000 feet. The annual rainfall, which is fairly well distributed throughout the year, amounts to 70 to 90 inches. The mean annual soil temperature is 71° F. Kaneohe soils are geographically associated with Alaeloa, Lolekaa, and Waikane soils.

These soils are used for pasture, homesites, and urban development. The natural vegetation consists of guava, Boston fern, sensitive plant, glenwoodgrass, and hilograss. Kaneohe silty clay, 3 to 8 percent slopes (KgB).—This soil occupies uniform slopes. Included in mapping were

small areas of reddish-colored soils and areas of dark-brown soils that formed in gravelly alluvium.

In a representative profile the surface layer is dark reddish-brown silty clay about 14 inches thick. The subsoil, 40 to more than 50 inches thick, is dusky-red and dark-red silty clay that has subangular blocky structure. The substratum is soft, weathered gravel. The soil is slightly acid in the surface layer and strongly acid in the surface. the subsoil.

Permeability is moderately rapid. Runoff is slow to medium, and the erosion hazard is slight. The available water capacity is 1.2 inches per foot in the surface layer and 1.4 inches per foot in the subsoil. In places roots penetrate to a depth of 5 feet or more.

Representative profile: Island of Oahu, lat. 21°22′44′′ N. and long. 157°47′36″ W.

Clsa—3 to 8 inches, dark reddish-brown (5YR 3/3) silt loam, reddish brown (5YR 4/3) when dry; weak, medium and thin, platy structure breaking to weak, medium and thin, platy structure breaking to weak, medium and fine, subangular blocky; soft, friable, slightly sticky and nonplastic; few roots; few pores; slight effervescence with hydrogen peroxide; slight effervescence with hydrogen pore; to lone, reddish brown (5YR 4/3) when dry; massive; soft, reddish brown (5YR 4/3) when dry; many interstitial pores; the lower 4 inches has weak, thin, platy structure and contains some black sand between the plates; has a pseudosand appearance under hand lean; few black concretions less than 1 millimeter in size; slight effervescence with hydrogen peroxide; slight effervescence with hydrogen peroxide; slight effervescence with hydrogen peroxide, slightly sticky and nonplastic; many roots; many fine pores; few black concretions less than 1 millimeter in size; slight effervescence with hydrogen peroxide or hydrochloric acid; moderately alkaline; abrupt, wavy boundary. 4 to 9 inches thick.

C4sa—27 to 34 inches, black (10YR 2/1) fine sandy loam, dark gray (10YR 4/1) when dry; single grain; loose, nonsticky and nonplastic; few roots; common pieces of weathered coral up to 2 inches in diameter; slight effervescence with hydrochloric acid; mildly alkaline; clear, wavy boundary, 3 to 8 inches thick.

C5sa—34 to 63 inches, black (10YR 2/1) silt loam, dark gray (10YR 4/1) when dry; massive; hard, very friable, slightly sticky and slightly plastic; common pieces of weathered coral up to 2 inches in diameter; water table begins at a depth of 35 inches; slight effervescence with hydrochloric acid; mildly alkaline.

The A horizon has platy structure in places o

The A horizon has platy structure in places or it is loose and fluffy. It ranges from silt loam to silty clay loam in texture. The depth to the water table ranges from 12 to 40 inches.

This soil is used for wildlife habitat and pasture, but it has low grazing value. It is not used for crops, because of poor drainage and high salt content. Small areas are used for urban development. (Capability classification VIIw, nonirrigated; pasture group 1)

Keawakapu Series

This series consists of well-drained, extremely stony soils on uplands on the island of Maui. These soils developed in volcanic ash. They are gently sloping to moderately steep. Elevations range from 100 to 800 feet. The annual rainfall amounts to 10 to 20 inches. Most of the rainfall occurs in fall and winter. The mean annual soil temperature is 76° F. Keawakapu soils are geographically associated with Kamaole, Makena, and Oanapuka soils.

These soils are used for pasture and wildlife habitat.

The natural vegetation consists of feather fingergrass, ilima, kiawe, uhaloa, and zinnia.

Keawakapu extremely stony silty clay loam, 3 to 25 percent slopes (KNXD).—This soil is on low uplands. Included in mapping were small areas of Kamaole and Oanapuka soils.

In a representative profile the surface layer, about 2 inches thick, is dark reddish-brown extremely stony silt loam that has platy structure. The subsoil, about 16 inches thick, is dark reddish-brown silty clay loam and silty clay that has prismatic and subangular blocky structure. The substratum is fragmental Aa lava that has a little soil material in the voids. The soil is neutral in the surface layer and subspil.

Permeability is moderate. Runoff is slow to medium, and the erosion hazard is slight to moderate. The available water capacity is about 1.5 inches per foot of soil. In places roots penetrate to a depth of 30 inches.

Representative profile: Island of Maui, lat. 20°48'12" N. and long. 156°25'58" W.

and long. 156°25′58′ W.

Al—0 to 2 inches, dark reddish-brown (5YR 3/3) extremely stony silt loam, reddish brown (5YR 4/4) when dry; moderate, medium and thick, platy structure; soft, very friable, slightly sticky and slightly plastic; plentiful fine roots; common fine and very fine pores; has gritty feel; few, fine, black concretions; 15 to 30 percent stones; delayed strong effervescence with hydrogen peroxide; neutral; clear, wavy boundary. 1 to 4 inches thick.

B21—2 to 9 inches, dark reddish-brown (5YR 3/3) very stony slity clay loam, dark reddish brown (5YR 3/4) when dry; weak, coarse, prismatic structure; soft, friable, sticky and plastic; plentiful fine roots; common fine pores; few, hard, saud-size aggregates that are resistant to crushing; few, fine, black concretions; 15 to 30 percent stones; strong effervescence with hydrogen peroxide; neutral; gradual, wavy boundary. 5 to 10 inches thick.

B22—9 to 18 inches, dark reddish-brown (5YR 3/3) slity clay, dark reddish brown (5YR 3/4) when dry; moderate, fine and very fine, subangular blocky structure; slightly hard, friable, sticky and plastic; few fine roots; many fine and medium pores; nearly continuous, tpin coatings on peds; common, hard, sand-size aggregates that are resistant to crushing; about 5 percent cobblestones and stones; few, fine, black concretions; strong effervescence with hydrogen peroxide; neutral; clear, wavy boundary. 7 to 10 inches thick.

IIC—18 inches, fragmental Aa lava that contains a little soil material in the voids.

IIC—18 inches, fragmental As lava that contains a little soil material in the voids.

The depth of the soil over fragmental As lava ranges from 12 to 30 inches. Stones cover 3 to 15 percent of the surface. The A horizon ranges from 5YR to 7.5YR in hue, from 3 to 4 in value when moist, and from 2 to 3 in chroma when moist and 3 to 4 when dry. The B horizon ranges from 3 to 4 in value when dry and from 3 to 4 in chroma when moist. The texture is siity clay loam or sitty clay. In a few places the lower part of the B porizon and the IIC horizon effervesce with hydrochlosic acid. with hydrochloric acid-

This soil is used for pasture and wildlife habitat. (Capability classification VIs, nonirrigated; pasture group 1)

<u>Kekaha Series</u>

This series consists of well-drained soils on alluvial fans and flood plains on the island of Kauai. These soils developed in alluvium washed from upland soils. They are nearly level to steep. Elevations range from nearly sea level to 150 feet. The annual rainfall amounts to 20 to 25 inches. The mean annual soil temperature is 74° F. Kekaha soils are geographically associated with Lualua-lei and Nohili soils.

These soils are used for irrigated sugarcane, pastureand wildlife habitat. The natural vegetation consists of

kon haole, kinwe, klu, and fingergrass.

Kekaha silty clay, 0 to 2 percent slopes (KoA).—This soil is on flood plains and alluvial fans. Included in mapping were small areas of stony soils.

In a representative profile the surface layer is dark reddish-brown silty clay about 21 inches thick. The subsoil is dark reddish-brown silty clay and clay more than 49 inches thick. The substratum is clayey alluvium. The silt is mildly allusing to neutral throughout the profile

49 inches thick. The substratum is clayey alluvium. The soil is mildly alkaline to neutral throughout the profile. Permeability is moderate. Runoff is slow, and there is no erosion hazard. The available moisture capacity is about 1.8 inches per foot of soil. In places roots penetrate to a depth of 5 feet or more.

Representative profile: Island of Kauai, lat. 21°59'0" N. and long. 159°43'19" W.

Representative profile: Island of Knuai, lat. 21°59'0'
Representative profile: Island of Knuai, lat. 21°59'0'
And long. 159°43'19'' W.

Ap1—0 to 7 inches, dark reddish-brown (5XR 3/2) silty clay, dark reddish brown (5XR 3/3) when dry; moderate, fine and very fine, granular structure; very hard, friable, sticky and plastic; plentiful roots; strong effervescence with hydrogen peroxide; mildly alkaline; clear, smooth boundary. 6 to 3 inches thick.

Ap2—7 to 14 inches, dark reddish-brown (5XR 3/3), moist and dry, silty clay; weak and moderate, fine and very fine, subangular blocky structure; very hard, friable, sticky and plastic; plentiful roots; moderate effervescence with hydrogen peroxide; mildly alkaline; clear, smooth boundary. 6 to 3 inches thick.

Alb—14 to 21 inches, dark reddish-brown (5YR 3/3) silty clay; bands of dark reddish brown (5YR 2/2), reddish brown (5YR 4/4) when dry; weak, fine, subangular blocky structure; hard, friable, sticky and plastic; plentiful roots; many fine and medium pores; thin, patchy clay coatings in pores and on peds; moderate effervescence with hydrogen peroxide; mildly alkaline; abrupt, smooth boundary. 6 to 9 inches thick.

B21—21 to 28 inches, dark reddish-brown (5YR 3/3) silty clay, dark reddish brown (5YR 3/4) when dry; massive; medium, subangular blocky structure in places; very hard, firm, sticky and plastic; few roots; many fine and medium pores; moderate effervescence with hydrogen peroxide; mildly alkaline; gradual, wavy boundary. 5 to 9 inches thick.

B22—28 to 44 inches, dark reddish-brown (2.5YR 3/4) clay, reddish brown (2.5YR 4/3) when dry; weak, medium, sticky and plastic; few roots; many fine and medium pores; moderate effervescence with hydrogen peroxide; mildly alkaline; gradual, wavy boundary. 12 to 20 inches thick.

B23—44 to 70 inches, dark reddish-brown (2.5YR 3/4) clay, weak red (2.5YR 4/2) when dry; weak, medium, subangular blocky structure; hard, firm, sticky and plastic; few roots; many fine pores; common patchy pressure cutans; vertical channels that

In places the A horizon is extremely stony or is clay. The B horizon ranges from 2.5YR to 5YR in hue.

This soil is used for irrigated sugarcane and pasture. (Capability classification I if irrigated, IVc if nonirrigated; sugarcane group 1; pasture group 2; woodland group 4)

Kekaha silty clay, 2 to 6 percent slopes (KoB).—On this soil, runoff is medium and the erosion hazard is slight to moderate. Included in mapping were a few small areas of stony soils and small areas where the slope is more than

6 percent.
This soil is used for irrigated sugarcane and pasture.
(Capability classification IIe if irrigated, IVc if nonirrigated; sugarcane group 1; pasture group 2; woodland

Kekaha clay, 0 to 2 percent slopes (KobA).—This soil is underlain by marine clay and has mottles in the subsoil. Workability is difficult. Runoff is slow, and there is

no erosion hazard.

This soil is used for irrigated sugarcane and pasture.
(Capability classification I if irrigated, IVc if nonirrigated; sugarcane group 1; pasture group 2; woodland

Kekaha extremely stony silty clay loam, 0 to 35 percent slopes (KOYE).—On this soil, runoff is slow to medium and the erosion hazard is no more than moderate.

This soil is used for pasture and wildlife habitat. (Capability classification VIs, nonirrigated; pasture group 2; woodland group 4)

Kemoo Series

This series consists of well-drained soils on uplands on the island of Oahu. These soils developed in material weathered from basic igneous rock. They are gently slop-ing to very steep. Elevations range from 300 to 1,200 feet. The annual rainfall amounts to 35 to 60 inches, most of which occurs between November and April. The mean annual soil temperature is 71° F. Kemoo soils occur mainly on the windward slopes of the Waianae Range and from Waimea Bay to Kahuku on the Koolau Range. They are geographically associated with Halawa, Mahana, and Paumalu soils.

These soils are used mainly for pasture. Small areas are used for sugarcane. The natural vegetation consists of guava, koa haole, Christmas berry, lantana, and

bermudagrass

Kemoo silty clay, 12 to 20 percent slopes (KpD).—This soil occurs on uplands. Included in mapping were small areas of silty clay loam or silt loam. These areas are at the higher elevations. The soils in these included areas have a concentration of heavy minerals in the surface layer. Also included were small, eroded spots and stony

In a representative profile the surface layer is very dusky red to dark reddish-brown, subangular blocky silty clay about 12 inches thick. The subsoil, about 55 inches thick, is dark reddish-brown to dusky-red silty clay that has subangular blocky structure. The substratum is soft, weathered rock. The soil is slightly acid in the surface layer and slightly acid to neutral in the subsoil.

Permenbility is moderate to moderately rapid. Runoff is medium, and the erosion hazard is moderate. The available water capacity is 1.4 inches per foot of soil. Workability is slightly difficult because of the slope. In places roots penetrate to a depth of 5 feet or more

Representative profile: Island of Oahu, lat. 21°33′00′′ N. and long. 158°07′23′′ W.

Ap1—0 to 4 inches, very dusky red (2.5YR 2/2) silty clay, dusky red (2.5YR 3/2) when dry; moderate, very fine, granular and subangular blocky structure; very hard, firm, sticky and plastic; abundant fine, medium, and coarse roots; common, very fine and fine, interstitial and tubular pores; strong effervescence with hydrogen peroxide; slightly acid; clear, smooth boundary. 3 to 5 inches thick.

Ap2—4 to 12 inches, dark reddish-brown (2.5YR 3/4), moist and dry, silty clay; strong, very fine and fine, subangular blocky structure; hard, firm, sticky and plastic; abundant fine, medium, and coarse roots; many, very fine, tubular pores; strong effervescence with hydrogen peroxide; slightly acid; gradual, smooth boundary. 6 to 9 inches thick.

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strongly acid; abrupt, smooth boundary. 8 to 10 inches thick.

B1—10 to 15 inches, dark-brown (10YR 3/3) silty clay, dark yellowish brown (10YR 3/4) when dry; moderate, very fine and fine, subangular blocky structure; hard, friable, sticky and plastic; plentiful fine roots; many very fine, fine, and medium, tubular pores; continuous, thin coatings on ped faces; evidence of much worm activity; many, hard, earthy lumps; common, soft, strongly weathered pebbles distinctly yellower than matrix, and smeary; very strongly acid; clear, smooth boundary. 4 to 0 inches thick.

B211—15 to 22 inches, dark-brown (10YR 3/3) silty clay, dark brown (10YR 4/3) when dry; strong, very fine to medium, blocky and subangular blocky structure; hard, friable, sticky and plastic; few fine roots; many very fine, fine, and medium, tubular pores; continuous, thick clay films on ped faces and in pores; dark-brown (7.5YR 4/4 moist), continuous, thick clay films in root channels; many, hard, earthy lumps, compact in place; very strongly acid; clear, smooth boundary. 4 to 10 inches thick.

B221—22 to 33 inches, dark-brown (10YR 3/3) silty clay, dark brown (10YR 4/3) when dry; strong, medium, subangular blocky structure and strong, very fine and fine, angular blocky structure and strong, very fine and fine, angular blocky structure and strong, very fine and fine, angular blocky structure and strong, very fine and fine, angular blocky structure and strong, very fine and fine, angular blocky structure; hard, friable, sticky and plastic; few fine roots; common, very fine and fine, tubular pores; continuous, thick clay films on ped faces and dark-brown (10YR 4/3) when dry; strong, very fine and fine, blocky and subangular blocky structure; hard, friable, sticky and plastic; few fine roots; many, fine and very fine, tubular pores; reddishbrown (5YR 4/4 moist), continuous, thin (lay films on ped faces and dark-brown (10YR 4/3) when dry; moderate, very fine and fine, subangular blocky structure; hard, friable, slightly sticky and slightly plastic; fe

tremely acid; clear, smooth boundary. 13 to 15 inches thick.
5 to 62 inches, dark yellowish-brown (10IR 3/4) loam, yellowish brown (10IR 5/4) when moist; moderate to weak, very fine and fine, subangular blocky structure; hard, friable, slightly sticky and slightly plastic; few very fine roots; many, very fine and fine, tubular pores; reddish-brown (5IR 4/4 moist), continuous, thin clay films on ped faces and in pores; 20 to 25 percent weathered rock fragments that are less weathered than those in the B24t horizon; extremely acid. B25t-55 horizon; extremely acid.

The depth to strongly weathered gravel and stones ranges from 40 to more than 60 inches. The strongly weathered, soft gravel and stones range from none to many throughout the solum. The A horizon ranges from 2 to 3 in value and chroma when moist. The Bt horizon ranges from 3 to 4 in value when moist and from 3 to 6 in chroma when moist. The texture of the B24t and B25t horizons ranges from loam to silty clay. The texture to silty clay.

This soil is used for pasture, homesites, truck crops, bananas, and papaya. (Capability classification IIe, non-irrigated; pasture group 8; woodland group 7)

Lolekaa silty clay, 8 to 15 percent slopes (loC).—On this soil, runoff is slow to medium and the erosion hazard is slight to moderate. Workability is slightly difficult because of the slope. Included in mapping were small,

eroded spots and small, gravelly areas.

This soil is used for pasture, homesites, papaya, and

bananas. (Capability classification IIIe, nonirrigated; pasture group 8; woodland group 7)

Lolekaa silty clay, 15 to 25 percent slopes (LoD).—This soil is on side slopes of terraces and along drainageways. Runoff is medium, and the erosion hazard is moderate. Workability is slightly difficult because of the slope. Included in mapping were small, eroded spots and small,

gravelly areas. This soil is used for pasture. (Capability classification IVe, nonirrigated; pasture group 8; woodland group 7)
Lolekaa silty clay, 25 to 40 percent slopes (lof).—This soil occurs along drainageways and on fans adjacent to the Koolau Range. Runoff is medium to rapid, and the erosion hazard is moderate to severe. Workability is difficult because of the slope. Included in mapping were

difficult because of the slope. Included in mapping were small, eroded spots and small, gravelly areas.

This soil is used for pasture. (Capability classification VIe, nonirrigated; pasture group 8; woodland group 7)

Lolekaa silty clay, 40 to 70 percent slopes (LoF).—This soil occurs along drainageways and on fans adjacent to the Koolau Range. Runoff is rapid, and the erosion hazard is severe. It is impractical to cultivate this soil.

This soil is used for pasture. (Capability classification VIIe, nonirrigated; pasture group 8; woodland group 14)

Lualualei Series

This series consists of well-drained soils on the coastal plains, alluvial fans, and on talus slopes on the islands of Kauai, Oahu, Molokai, and Lanai. These soils developed in alluvium and colluvium. They are nearly level and gently sloping. Elevations range from 10 to 125 feet. In most places the annual rainfall amounts to 18 to 30 inches but it is as low as 10 inches on Lanai and as high inches, but it is as low as 10 inches on Lanai and as high as 50 inches on Kauai. Most of the rainfall occurs during as 50 inches on Kauai. Most of the rainfall occurs during storms in the period from November to April. There is a prolonged dry period in summer. The mean annual soil temperature is 75° F. Lualualei soils are geographically associated with Honouliuli, Jaucas, and Kekaha soils.

These soils are used for sugarcane, truck crops, pasture, wildlife habitat, urban development, and military installations. The natural vegetation consists of kiawe, koa haole, bristly foxtail, uhaloa, and fingergrass.

Lualualei clay, 0 to 2 percent slopes (UA).—This soil is on alluvial fans. Included in mapping were small, stony areas and small areas of Ewa soils.

In a representative profile the surface layer, about 10

In a representative profile the surface layer, about 10 inches thick, is very dark grayish-brown, very sticky and inches thick, is very dark grayish-brown, very sticky and very plastic clay that has prismatic structure. The next layer, 37 to more than 42 inches thick, is very dark grayish-brown, very sticky and very plastic clay that has prismatic structure. In addition, it has gypsum crystals. The soil is underlain by coral, gravel, sand, or clay at depths below 40 inches. This soil cracks widely upon drying. It is neutral in the surface layer and medium acid to moderately alkaline in the underlying layers.

Permeability is slow. Runoff is slow, and the erosion hazard is no more than slight. The available water capac-

ity is about 1.4 inches per foot of soil. In places roots penetrate to a depth of 5 feet or more. The shrink-swell potential is high.

Representative profile: Island of Oahu, lat. 21°25′10″ N. and long. 158°09′00″ W.

and long. 158°09'00' W.

All—0 to 1 inch, very dark grayish-brown (10YR 3/2) clay, very dark gray (10YR 3/1) when moist; strong, fine and very fine, granular structure; very hard, firm, very sticky and very plastic; abundant fine roots; many, fine, interstitial pores; few light-colored sand grains; vertical cracks up to 2½ inches wide; strong effervescence with hydrogen peroxide; neutral; abrupt, smooth boundary. ½ inch to 1½ inches thick.

Al2—1 inch to 10 inches, very dark grayish-brown (10YR 3/2) clay, very dark gray (10YR 3/1) when moist; moderate, coarse, prismatic structure breaking to moderate, medium, subangular blocky; very hard, firm, very sticky and very plastic; abundant fine roots; many, fine, tubular pores; some organic litter in the cracks; strong effervescence with hydrogen peroxide; neutral; gradual, smooth boundary. S to 12 inches, very dark grayish-brown (10YR 3/2)

nn the cracks; strong enervescence with hydrogen peroxide; neutral; gradual, smooth boundary. S to 12 inches thick.

AC—10 to 22 inches, very dark grayish-brown (10YR 3/2) clay, very dark grayish brown (10YR 3/2) when moist; moderate, coarse, prismatic structure breaking to moderate, medium, subangular blocky; very hard, firm, very sticky and very plastic; abundant fine roots; many, fine, tubular pores; common slickensides; few black specks; few coral sand grains; strong effervescence with hydrogen peroxide; neutral; clear, smooth boundary. 10 to 12 inches thick.

C1—22 to 30 inches, very dark grayish-brown (10YR 3/2), moist and dry, clay; moderate, medium and coarse, subangular blocky structure; hard, firm, very sticky and very plastic; plentiful fine and medium roots, mainly matted between cleavage planes; few, fine and very fine, tubular pores; many weakly grooved slickensides; common black stains in pores and in dendritic pattern on ped faces; few light-colored sand grains; common shiny specks; strong effervescence with hydrogen peroxide; neutral; gradual, smooth boundary. 7 to 10 inches thick.

C2cs—30 to 40 inches, very dark grayish-brown (10YR 3/2), moist and dry, clay; strong, medium and coarse, subangular blocky structure; hard, firm, very sticky and very plastic; few fine roots matted between faces; few, fine, tubular pores; many deeply grooved slickensides; many, fine and medium, gypsum crystals; common black stains in pores and on peds; common shiny specks; few light-colored sand grains; strong effervescence with hydrogen peroxide; medium acid; abrupt, smooth boundary. 17 to 20 inches thick.

C3cs—49 to 60 inches. very dark grayish-brown (10YR 3/2), moist and dry, clay; strong, coarse, subangular

thick.

49 to 60 inches, very dark grayish-brown (10YR 3/2), moist and dry, clay; strong, coarse, subangular blocky structure; extremely hard, very firm, very sticky and very plastic; few fine roots matted between peds; few, fine, tubular pores; many deeply grooved slickensides; common, medium and coarse, gypsum crystals; few shiny specks; strong effervescence with hydrogen peroxide; medium acid.

The All horizon is granular when dry but massive when wet. Because of the type of clay, there is considerable swelling and shrinking of the soil as a result of alternate wetting and drying. When the soil dries, it cracks and forms huge blocks 1 foot or more in diameter. When it is wet there is no evidence of the blocks. The A and C horizons range from 7.5TR to 10TR in hue and from 2 to 4 in value. Chroma is either 1 or 2. Gypsum crystals 1/2 inch to 3 inches in diameter are common in the profile, generally below a depth of 30 inches. The All horizon is granular when dry but massive

This soil is used for sugarcane, truck crops, pasture, wildlife habitat, urban development, and military installations. The very sticky and very plastic nature of the

clay makes cultivation difficult and practical only within a narrow range of moisture content. Because of the high shrink-swell potential, considerable care is necessary when using this soil as a site for buildings or highways. (Capability classification IIIs if irrigated, VIs if nonirrigated; sugarcane group 4; pasture group 2; woodland group 4)

Lualualei clay, 2 to 6 percent slopes (lu8).—On this soil, runoff is slow and the erosion hazard is slight. Included in mapping were small, stony areas and small areas where the slope is as much as 12 percent.

This soil is used for sugarcane, truck crops, pasture, urban development, and military installations. (Capability classification IIIe if irrigated, VIs if nonirrigated; sugarcane group 4; pasture group 2; woodland group 4)

Lualualei stony clay, 0 to 2 percent slopes (lvA).—This soil occurs on Oahu on fans adjacent to drainageways. It is similar to Lualualei clay, 0 to 2 percent slopes, except that there are enough stones to hinder machine cultivation. a narrow range of moisture content. Because of the high

cultivation.

This soil is used for sugarcane, truck crops, pasture, and military installations. (Capability classification IIIs if irrigated, VIs if nonirrigated; sugarcane group 4; pasture group 2; woodland group 4)

Lualualei stony clay, 2 to 6 percent slopes (lvB).—This soil occurs on Oahu adjacent to drainageways. It is similar to Lualualei clay, 0 to 2 percent slopes, except that there are enough stones to hinder machine cultivation. Runoff is slow, and the erosion hazard is slight. Included in mapping were small areas where the slope Included in mapping were small areas where the slope

is 6 to 12 percent.

This soil is used for urban development, military installations, pasture, truck crops, and sugarcane. (Capability classification IIIe if irrigated, VIs if nonirrigated; sugarcane group 4; pasture group 2; woodland group 4)

Lualualei extremely stony clay, 3 to 35 percent slopes

(IPE).—This soil occurs on talus slopes on Oahu and Kauai. The slope range is 3 to 35 percent, but in most places the soil is moderately sloping to steep. This soil is similar to Lualualei clay, 0 to 2 percent slopes, except that there are many stones on the surface and in the profile. It is impractical to cultivate this soil unless the stones are removed. Runoff is medium to rapid, and the erosion hazard is moderate to severe.

This soil is used for pasture. (Capability classification.)

VIIs, nonirrigated; pasture group 2; woodland group 4)

Mahana Series

This series consists of well-drained soils on uplands on the islands of Kauai and Oahu. These soils developed in volcanic ash. They are gently sloping to very steep. Elevations range from 1,000 to 3,000 feet. The annual rainfall amounts to 30 to 45 inches. The mean annual soil temperature is 67° F. Mahana soils are geographically associated with Oli and Puu Opae soils on Kauai and with Kolekole soils on Oahu.

These soils are used for pasture, woodland, wildlife habitat, irrigated sugarcane, and water supply. The natural vegetation consists of puakeawe, aalii, ricegrass, molassesgrass, silver oak, yellow foxtail, lantana, joee, Japanese tea, passion flower, and associated plants.

Mahana silt loam, 6 to 12 percent slopes (MoC).—This soil occurs on ridgetops and moderately sloping uplands.

Niulii Series

This series consists of well-drained soils on uplands on the island of Molokai. These soils formed in local allu-vium and colluvium and were influenced by volcanic ash. They are sloping to hilly. On Molokai, elevations range from 1,250 to 2,000 feet. The annual rainfall amounts to 70 to 90 inches and is fairly well distributed throughout the year Cloud and for cover persist throughout most of 70 to 90 inches and is fairly well distributed throughout the year. Cloud and fog cover persist throughout most of the day. The mean annual soil temperature is 68° F. Niulii soils are geographically associated with Olokui soils and the medium-textured variant of Niulii soils.

In this survey area a medium-textured variant of the Niulii series was mapped. This soil, Niulii silty clay loam, medium textured variant, 7 to 30 percent slopes, is described in alphabetical order, along with other mapping units of this series.

ping units of this series.

These soils are used for pasture and wildlife habitat. The natural vegetation consists of carpetgrass, glenwoodgrass, ohia, false staghornfern, treefern, creeping Chinese violets, and sedges.

Niulii silty clay loam, 7 to 30 percent slopes (NLE). This soil occurs in areas where the topography is sloping

In a representative profile the surface layer, about 11 inches thick, is dark-brown silty clay loam and silty clay that has subangular blocky structure. The subsoil, about 13 inches thick, is dark-brown silty clay that has subangular and angular blocky structure. The substratum is soft, highly weathered stones and gravel. The soil is very strongly acid throughout the profile.

Permeability is moderately rapid. Runoff is slow to medium, and the erosion hazard is slight to moderate. In places roots penetrate to a depth of 3 feet or more. Work-

ability is slightly difficult because of the slope.

Representative profile: Island of Molokai, lat. 21°06′56″ N. and long. 156°47′23″ W.

and long. 156°47′23″ W.

A11—0 to 5 inches, dark-brown (10YR 3/3) silty clay loam, dark gray (10YR 4/1) when dry; strong and moderate, fine, subangular blocky structure; very hard, friable, sticky and plastic; many roots; many interstitial pores; very strongly acid; clear, wavy boundary. 4 to 6 inches thick.

A12—5 to 11 inches, dark-brown (10YR 3/3) silty clay, dark gray (10YR 4/1) when dry; moderate, fine, subangular blocky structure; very hard, friable, sticky and plastic; many roots; many, very fine, tubular pores and common, fine, tubular pores; very strongly acid; clear, wavy boundary. 5 to 8 inches thick.

B22—11 to 24 inches, dark-brown (10YR 3/3) silty clay, dark grayish brown (10YR 4/2) when dry; moderate, fine and medium, subangular and angular blocky structure; slightly hard, friable, sticky and plastic;

structure; slightly hard, friable, sticky and plastic; few roots; many, very fine, tubular pores and common, fine, tubular pores; common oxide coatings on peds; gritty feeling because of few very fine rock fragments; very strongly acid; clear, wavy boundary. 11 to 22 inches.

C—24 to 40 inches, soft, highly weathered stones and pebbles,

ome of which break down to smeary silty clay loam.

IIR-40 inches, hard pahoehoe lava.

The A horizon is 10YR in hue. The B horizon ranges from 10YR to 7.5YR in hue. In places a few, fine, distinct, reddishbrown mottles occur in the A horizon and few to common, fine, reddish-brown mottles in the B horizon. This soil has a tendency to harden irreversibly upon drying.

This soil is used for pasture and wildlife habitat. (Capability classification VIe, nonirrigated; pasture group 9; woodland group 8)

Niulii silty clay loam, medium textured variant, 7 to 30 percent slopes (NME).—This soil occurs on East Molokai, mainly on narrow ridges bordered by deep gulches. In most places the slope is 15 to 25 percent. Elevations range from 500 to 2,500 feet. The annual rainfall amounts to 40 to 60 inches. In a representative profile the texture of the subsoil is coarser than is typical of the Niulii series, and the structure is weaker.

ries, and the structure is weaker.

This soil is dark brown throughout the profile. The surface layer is silty clay loam about 8 inches thick. The subsoil is very friable silt loam, 22 to 27 inches thick. The substratum is soft, weathered rock. The soil is strangly said throughout the profile.

is strongly acid throughout the profile.

Permeability is moderately rapid. Runoff is slow to medium, and the erosion hazard is moderate to severe. Workability is slightly difficult to difficult because of the slope. In many places this soil is slightly eroded.

This soil is used mostly for pasture and wildlife habitat. Small areas are used for woodland. (Capability classification Vic. noninvigated: pasture group 9: woodland.

sification VIc, nonirrigated; pasture group 9; woodland

group 8)

Nohili Series

This series consists of poorly drained soils on constal plains on the island of Kauai. These soils developed in alluvium that was deposited over marly lagoon deposits. They are nearly level. Elevations range from nearly sea level to a few feet above sea level. The annual rainfall amounts to 20 to 40 inches. The mean annual soil temperature is 75° F. Nohili soils are geographically associated with Kaloko soils.

These soils are used for irrigated sugarcane. They are

all under cultivation.

Nohili clay (Nh).—This soil is on the coastal plains.
In a representative profile the surface layer is dark reddish-brown clay about 18 inches thick. The subsoil, about 15 inches thick, is mottled, dark-brown, very dark gray, and grayish-brown clay that has angular blocky structure. The substratum is marly clay that is underlain in places by dark-gray, noncalcareous clay. The surface layer is mildly alkaline and moderately alkaline.

Permeability is moderately slow. Runoff is slow, and there is no erosion hazard. This soil is subject to occasional flooding. Unless the soil is artificially drained, the water table is within 2 feet of the surface. The available water capacity is about 1.7 inches per foot of soil. In places roots penetrate to the water table. Workability is

Representative profile: Island of Kauai, lat. 21°59'36.8" N. and long. 159°44'28.8" W.

Ap1—0 to 5 inches, dark reddish-brown (5YR 3/2) clay, dark reddish brown (5YR 3/2) when dry; strong, fine and very fine, subangular blocky structure; extremely hard, firm, very sticky and very plastic; no roots; moderate effervescence with hydrogen peroxide; moderate effervescence with hydrochloric acid; mildly alkaline; abrupt, smooth boundary. 4 to 6 inches thick.

thick.
to 18 inches, dark reddish-brown (5YR 3/3) clay,
brown (7.5YR 4/2) when dry; moderate, medium,
subangular blocky structure; extremely hard, firm,

very sticky and very plastic; plentiful medium and fine roots; common medium and fine pores; moderate effervescence with hydrogen peroxide; slight effervescence with hydrogen peroxide; slight effervescence with hydrochloric acid; mildly alkaline; abrupt, wary boundary. It to 15 inches thick.

B21—18 to 23 inches, dark-brown (7.5TR 3/2) clay mottled with reddish brown (5TR 4/4) and dark gray (10YR 4/1), dark brown (5TR 4/4) and dark gray (10YR 4/1), dark brown (5TR 4/4) and very plastic; plentiful medium roots and few fine nore; moderate, fine to coarse, angular blocky structure; extremely hard, firm, very sticky and very plastic; plentiful medium roots and few fine and very fine roots; common medium pores and few fine pores; moderate effervescence with hydrochloric acid; few, soft, black concretions; mildly alkaline; abrupt, smooth boundary. 4 to 6 inches thick.

B22—23 to 29 inches, very dark gray (10YR 3/1) clay that contains blotches of light gray (10YR 3/1) and specks of dark reddish brown (2.5TR 3/4), very dark gray (10YR 3/1) when dry; moderate, coarse, angular blocky structure; extremely hard, firm, very aticky and very plastic; abundant fine roots, plentiful very fine roots, and few micro roots; many fine pores and common very fine pores; slight effervescence with hydrochloric acid; few pressure cutans and slickersides; moderately alkaline; gradual, smooth boundary. 5 to 7 inches thick.

B3—29 to 33 inches, grayish-brown (10YR 5/4), dark yellowish brown (10YR 4/4), and black (10YR 2/1); gray (10YR 5/1) when dry; moderate, medium and coarse, angular blocky structure; extremely hard, firm, very sticky and very plastic; plentiful medium and fine roots; common medium and fine pores; slight effervescence with hydrochloric acid; moderately alkaline; gradual, smooth boundary. 4 to 6 inches thick.

IIC1—33 to 43 inches, light brownishgray (2.5Y 6/2) cemented layers that contain lenses of clay mottled with brown (7.5YR 5/4) and yellowish brown (10YR 5/4), dark gray (10YR 4/1), and light gray (N 7/0) when dry; la

moderately alkaline; abrupt, smooth boundary. 8 to 12 inches thick.

IIIC2—43 to 120 inches, dark-gray (N 4/0) clay that has some coatings of olive brown (2.5Y 4/4), very dark gray (5Y 3/1) when dry; weak, coarse, angular blocky structure; extremely hard, firm, very sticky and very plastic; abundant fine, very fine, and micro roots; many fine, very fine, and micro pores; very slight effervescence with hydrogen peroxide; no effervescence with bydrochloric acid; yellow and white specks are visible under 10-power lens; many fine, white, elongated crystals form on outside of clods when they dry; very strongly acid.

The A horizon ranges from 2 to 3 in chromn. The B2 horizon ranges from 5VR to 10VR in huc, from 1 to 3 in chroma, and from 2 to 3 in value. The B horizon has few to many mottles. The depth to the mari ranges from 20 to 40 inches.

This soil is used for irrigated sugarcane. (Capability classification IIIw if irrigated, Vw if nonirrigated; sugarcane group 3; pasture group 7)

Nonopahu Series

This series consists of moderately well drained soils on uplands on the island of Kauai. These soils developed in material weathered from basic igneous rock relatively high in olivine. They are gently sloping to moderately sloping. Elevations range from nearly sea level to 800

feet. The annual rainfall amounts to 23 to 40 inches. The mean annual soil temperature is 74° F. Nonopahu soils are geographically associated with Makaweli and Waikomo soils.

These soils are used for irrigated sugarcane and pasture. The natural vegetation consists of koa haole, klu, and feather fingergrass.

Nonopahu clay, 2 to 10 percent slopes (NnC).—This soil is on low ridges on uplands. Included in mapping were small areas where the slope is less than 2 percent. In a representative profile the surface layer is dark grayish-brown clay about 17 inches thick. The next layer, shout 48 inches thick in house and appropriate the surface of t

about 48 inches thick, is brown or grayish-brown clay and silty clay that has angular blocky and subangular blocky structure. This soil is underlain by soft, weathered rock. It is mildly alkaline throughout.

Permeability is moderately slow. Runoff is medium, and the erosion hazard is moderate. The available water capacity is about 1.3 inches per foot of soil. In places roots penetrate to a depth of 5 feet or more. Workability is difficult.

Representative profile: Island of Kauai, lat. 21°54′57" N. and long. 159°37′26.5" W.

Ap—0 to 17 inches, dark grayish-brown (10YR 4/2) clay, brown (7.5YR 4/2) when dry; moderate, coarse, granular structure; very hard, firm, sticky and plastic; common fine roots; many, medium, intersitial pores and few, medium, tubular pores; common, black concretions 1 millimeter to 5 millimeters in size; pockets of dark yellowish-brown (10YR 4/4) and dark grayish-brown (2.5Y 4/2) clay; moderate effervescence with hydrogen peroxide; nilidly alkaline; clear, wavy boundary. 15 to 20 inches thick.

C1—17 to 31 inches, brown (10YR 4/3) clay; pockets (about 40 percent) of mottled dark yellowish brown (10YR 4/4) and dark gray (10YR 4/1); light olive brown (2.5Y 5/4) when dry; weak, coarse, angular blocky structure; very hard, firm, sticky and plastic; many fine roots; few, medium, interstitial pores and many, medium, tubular pores; common concretions less than 2 millimeters in size; few slickensides; moderate effervescence with hydrogen peroxide; mildly alkaline; abrupt, wavy boundary. 12 to 16 inches thick.

alkaline; abrupt, wavy boundary. 12 to 16 inches thick.

C2—31 to 47 inches, grayish-brown (2.5\times 4/2) clay, light olive gray (5\times 6/2) when dry; weak, coarse, angular blocky structure; extremely hard, very firm, very sticky and very plastic; few fine roots; few, medium, tubular pores; common, fine, black, hard concretions; common slickensides; slight effervescence with hydrogen peroxide; mildly alkaline; clear, smooth boundary. 14 to 18 inches thick.

C3—47 to 65 inches, brown (10\times 4/3) silty clay, brown (10\times 5/3) when dry; strong, medium, subangular blocky structure; very hard, firm, sticky and plastic; few fine roots; many interstitial pores; nearly continuous pressure cutans on ped faces; common slickensides; many, medium, black stains on peds; strong effervescence with hydrogen peroxide; mildly alkaline.

In places a few ironstone-gibbsite pebbles occur throughout

In places a few ironstone-gibbsite pebbles occur throughout the profile. The A horizon ranges from 2 to 4 in chroma and from 3 to 4 in value. The C horizon ranges from 10VR to 2.5V in hue, from 2 to 4 in chroma, and from 4 to 5 in value. Mottles in the C horizon range from few to common. Unless the soil is irrigated, cracks more than 1 centimeter wide and 20 inches or more deep develop in most years.

This soil is used for sugarcane and pasture. (Capability classification IIIe if irrigated, VIe if nonirrigated; sugarcane group 4; pasture group 2)

Rock Land

Rock land (rRK) is made up of areas where exposed rock ROCK land (1866) is made up of areas where exposed rock covers 25 to 90 percent of the surface. It occurs on all five islands. The rock outcrops and very shallow soils are the main characteristics. The rock outcrops are mainly basalt and andesite. This land type is nearly level to very steep. Elevations range from nearly sea level to more than 6,000 feet. The annual rainfall amounts to 15 to 60 inches

more than 0,000 feet. The annual rainfail amounts to 15 to 60 inches.

Rock land is used for pasture, wildlife habitat, and water supply. The natural vegetation at the lower elevations consists mainly of kiawe, klu, piligrass, Japanese tea, and koa haole. Lantana, guava, Natal redtop, and molassesgrass are dominant at the higher elevations. This land type is also used for urban development. In many land type is also used for urban development. In many areas, especially on the island of Oahu, the soil material associated with the rock outcrops is very sticky and very plastic. It also has high shrink-swell potential. Buildings on the steep slopes are susceptible to sliding when the soil is saturated. Foundations and retaining walls are susceptible to cracking. (Capability classification VIIs, nonirrigated)

Rock Outcrop

Rock outcrop (RO) consists of areas where exposed bedrock covers more than 90 percent of the surface. It occurs on all five islands. The rock outcrops are mainly basalt on an are islands. The rock outcrops are mainly basalt and andesite. This land type is gently sloping to precipitous. Elevations range from nearly sea level to 10,000 feet. Included in mapping were a small area of lithified coral sand on Molokai and small areas of coral outcrop along the coasts of other islands.

This land type is not critical to feet in the coasts.

This land type is not suited to farming. It is used for water supply, wildlife habitat, and recreation. (Capability classification VIIIs, nonirrigated)

Rough Broken Land

Rough broken land (rRR) consists of very steep land broken by numerous intermittent drainage channels. In most places it is not stony. It occurs in gulches and on mountainsides on all the islands except Oahu. The slope is 40 to 70 percent. Elevations range from nearly sea level to about 8,000 feet. The local relief is generally between 25 and 500 feet. Runoff is rapid, and geologic erosion is active. The annual rainfall amounts to 25 to more than 200 inches.

These soils are variable. They are 20 to more than 60 inches deep over soft, weathered rock. In most places some weathered rock fragments are mixed with the soil material. Small areas of rock outcrop, stones, and soil slips are common. Included in mapping were areas of colluvium and alluvium along gulch bottoms.

This land type is used primarily for watershed and wildlife habitat. In places it is used also for pasture and woodland. The dominant natural vegetation in the drier areas consists of guava, lantana, Natal redtop, bermudagrass, koa haole, and molassesgrass. Ohia, kukui, koa, and ferns are dominant in the wetter areas. Puakeawe, aalii, and sweet vernalgrass are common at the higher elevations. (Capability classification VIIe, nonirrigated)

Rough Broken and Stony Land

Rough broken and stony land (rRS) consists of very steep, stony gulches. The local relief is generally between 25 and 500 feet. Runoff is rapid, and geologic erosion is active. Elevations range from nearly sea level to 3,000 feet. The annual rainfall amounts to 20 to 40 inches.

The soil material is generally less than 20 inches deep over saprolite or bedrock. About 3 to 25 percent of the surface is covered with stones, and there are a few rock outcrops. Included in mapping were small areas of colluvium and alluvium along the bottoms of gulches.

This land type is used for pasture, wildlife habitat, and watershed. The dominant natural vegetation consists of lantana, koa, haole, klu, feather fingergrass, bermudagrass, and ilima. (Capability classification VIIs,

nonirrigated)

Rough Mountainous Land

Rough mountainous land (rRT) occurs in mountainous areas on all islands in the survey area. Is consists of very steep land broken by numerous intermittent drainage channels. In most places it is not stony. Elevations range from nearly sea level to more than 6,000 feet. The annual rainfall amounts to 70 to more than 400 inches. Over much of the area, the soil mantle is very thin. It ranges from 1 inch to 10 inches in thickness over saprolite. In most places the saprolite is relatively soft and

permeable to roots and water.

The land surface is dominated by deep, V-shaped valleys that have extremely steep side slopes and narrow ridges between the valleys. In most places the local relief exceeds 500 feet. The soil material on the narrow ridge-tops is similar to that of the Amalu and Olokui series. Rock land, rock outcrop, soil slips, and eroded spots make up 20 to 40 percent of the acreage.

This land type is used for water supply, wildlife habitat, and recreation. The natural vegetation consists of ohia, false staghornfern, treefern, vellow fortail, lantana.

ohia, false staghornfern, treefern, yellow foxtail, lantana, kukui, and puakeawe. (Capability classification VIIIe, nonirrigated)

Rubble Land

Rubble land (rRU) consists of areas where 90 percent of the surface is covered by stones or boulders. It occurs at the base of very steep to precipitous slopes in the western and southern parts of the island of Kanai. Elevations range from sea level to about 500 feet. The annual rainfall amounts to 22 to 50 inches.

This land type is used for wildlife habitat. The natural vegetation is mainly kon haole. (Capability classification VIIIs, nonirrigated)

Sandy Alluvial Land

Sandy alluvial land ((Si) occurs along the narrow coastal flats in the northern and northeastern parts of Lanai. It consists of recent stream deposits that vary widely in texture. Most areas are sandy and have few pebbles and stones. This land type is subject to flooding during the rainy season. In most places the slope is 0 to 5 percent, but in places it is as much as 15 percent. In areas exposed

TABLE 2.—Estimated

1				
	Depth	to	7045	Classification
Soil series and map symbols	Bedrock	Seasonal high water table	Depth from surface	Dominant USDA texture
Honouliuli: HxA, HxB	Feet >5	Feet >5	Inches 0-6S	Clay
Hoolehua: HyB3, HzA, HzB, HzC, HzE	>5	>5	0-15 15-64	Silty clay
Hulus: HNUD, HNUF	1-115	(1)	0-16 16-18 18-60	Silty clay
Hydrandepts: rHT For Tropaquods part of rHT, see Tropaquods.	. >5	>5	3-0 0-37 37-60	Peat
Inc: laA, laB, lbB, lbC, lcB, lcC	>5	>5	0-60	Clay or silty clay; cobbly in places
Io: ISD	>5	>5	0-30 30-39 39-45	Silty loam, silty clay loam, and clay loam Cinders Loam
Ioleau: loB, loC, loD2, loE2	>5	>5	0-61	Silty clay loam and silty clay
Jaucas: JaC, JfB, JkB, JL	>5	>5	0-60	Sand
JcC	>5	2-5	0-60	Sand
Kaena: KaB, KaC, KaeD, KanE, KavB, KavC, KaeB, KaeC.	>5	(4)	0-54	Stony clay
Kahana: KbB, KbC, KbD	>5	>5	0-61	Silty chay
Kahanui: KASD, KATD	>5	>5	- 0-30 30-60	Silty clay, clay, and ironstone fragments
Kailua: KBID	3. 5-5	>5	0-40	Silty clay and silty clay loam
Knimu: KCXD	2-5	>5	0-8 \$-20	Extremely stony peatAs lava.
Kaipoioi: KDIE, KDVE	>5	>5	0-61	Loam, silt loam, and silty clay loam
Kalae: KcB, KcC, KcC3, KcD3, KcE3		>5	0-41 41-67	Silty clay
Kalapa: KdD, KdE, KdF, KEHF	>5	>5	0-60	Silty clay or clay
Kalaupapa: KFID	1/2-11/2	>5	0-14 14	Silty clay loam and silt loamPahochoe lava.
Kalihi: Ke	>5	2-5	0-70	Clay
Kaloko: Kf, Kfa, Kfb	1	1-2	0-60	Clay and silty clay
Kamaole: KGKC, KGLC		>5	0-20 20	Silty clay loam and very stony silty clay As lava.
Kaneohe: KgB. KgC, KHMC, KHME, KHMF, KHOF.	>5	>5	0-60	Silty clay or silty clay loam
Kanepuu: KhB, KhB2, KhC, KhC2		>5	0-61	Silty clay
Kapaa: KkB, KkC, KkD, KkE, KlG		>5	0-60	Silty clay and clay loam
Kapuhikani: KKTC		>5	0-20 20-27 27	Extremely stony clay and claySoft weathered rockBedrock.

See factuates at end of table

operties—Co					Corrosivit	у
Unified	Permeability	Available water capacity	Reaction	Shrink-swell potential	Uncoated steel	Concrete
			a II mius		_	
CL	Inches per hour 0, 20-0, 63	Inches per inch of soll 0. 14-0. 16	pH salue 6. 6-7. 8	High	Low	Low. High.
IH IH	0. 63-2. 0 0. 63-2. 0	0. 14-0. 16 0. 15-0. 17	3. 8 -4 . 5 6. 1-6. 5	Moderate Low	Low	Low.
H	2.0-6.3	0. 12-0. 14	5. 1-5. 5	(2)	High	Moderate.
IH	< 0. 06 2. 0−6. 3	0. 12-0. 14	4. 5–5. 0	Low	High	High.
et OH	6. 3–20. 0 2. 0–6. 3 2. 0–6. 3	0, 20-0, 30 0, 16-0, 18 0, 06-0, 08	3. S-4. 5 3. 7-1. 5 4. 0-4. 5	(3) Low	High High High	High. High. High.
CL MH	0. 20-0. 63	0. 13-0. 15	6. 6-7. 3	Moderate	Low	Low.
мн	2. 0-6. 3 2. 0-6. 3 2. 0-6. 3	0. 15-0. 17 0. 15-0. 17	6. 6-7. S 7. 9-8. 4 7. 9-8. 4	LowLow	Low Low	Low. Low. Low.
ML MH	0. 06-0. 63	0. 12-0. 14	4. 0-5. 0	Moderate	High	High.
SP .	6, 3-20, 0	0. 05-0. 07	6. 6–7. S	Low	Low	Low.
SP	6. 3-20. 0	0. 03-0. 07	7. 9-8. 4	Low	High	High.
CH	0. 06-0. 63	0. 11-0. 13	6. 6–7. 3	High	Low	Low.
MH	2, 0-6. 3	0. 10-0. 12	4. 5-7. 3	Moderate to low	Moderate to low	Moderate to lo
MH ML or MH	2. 0-6. 3 2. 0-6. 3	0. 10-0. 12 0. 10-0. 12	4. 5-5. 0 4. 5-5. 0	Moderate	High	High. High.
OH or MH	2. 0-6. 3	0. 19-0. 21	4. 5-6. 0	(7)	High	High.
Pt	>20.0	0. 10-0. 15	6. 6–7. 3	Moderate	Low	Low.
OH or MH	2. 0-6. 3	0. 13-0. 15	6. 6-7. 8	Moderate	Low	Low.
MH ML	2. 0-6. 3 2. 0-6. 3	0. 12-0. 14 0. 12-0. 14	5. 1-5. 5 5. 1-5. 5	Moderate	High	Moderate. Moderate.
ИН	2, 0-6, 3	0. 12-0. 14	4. 5-5. 0	Moderate:	High	High.
ML	0. 63-2. 0	0. 19-0. 21	6. 6-7. 3	Low	Low	Low.
СН	0. 06-0. 20	0. 12-0. 14	6. 1-7. 3	High	High	Low.
CH	0. 06-0. 63		6. 1-7. 8	High	High	Moderate.
мн-сн	0. 63–2. 0	0. 09-0. 11	6. 1-7. 8	Low	_ Low	Low.
мн	2, 0-6, 3	0. 11–0. 13	5. 1–6. 5	Moderate	High	Moderate.
ML-MH	0, 63-2. 0	0. 11-0. 13	6. 1-7. 3		_ Low	Low.
MH	2. 0-6. 3	0. 13-0. 15	4. 5-6. 0		High	_ Moderate.
CH ML	0. 06-0. 20 0. 06-0. 20	0. 11-0. 13 0. 05-0. 07	7. 4-7. 8 7. 9-8. 4	High	Low	Low.

. Table 2.—Estimated

,	Depth	ı to	D+h	Classification
Soil series and map symbols	Bedrock Seasonal high water table		Depth from surface	Dominant USDA texture
Kaupo: KLUD, KLVD	Feet 1½-3½	Feet >5	Inches 0-27 27	Very stony silty clay loam; extremely stor in places. Aa lava.
Kawaibapai: KIA, KIB, KIC, KIAA, KIAB,	>5	>5	0-22	Clay loam; stony or very stony in place
KIBC, KIEB.			22-54	Sandy loam
ICenau: Km A, Kma B, Kmb A	>5	13-4-3	0-34 34-39 39-57	Ciny and silty clay Consolidated coral sand Sand
Keahua: KnB, KnC, KnaB, KnaC, KnaD, KnbD, KncC, KnhC, KnsC.	>5	>5	. 0–62	Silty clay loam and clay loam; cobbly or ve stony in places.
Kealia: KMW	>5	1-33-5	0-63	Siltloam, loam, and fine sandy loam
Keawakapu: KNXD	>5	>5	0-9 9-18 18	Extremely stony silty clay loam
Kekaha: KoA, KoB, KobA, KOYE	>5	>5	0-70	Silty clay or clay; extremely stony in pla
Kemoo: KpB, KpC, KpD, KpE, KpF, KPZ.	>5	>5	0-66	Silty clay
Koele: KrB, KrC, KrD, KRL, KRX		>5	0-33 33-55	Silty clay loam. Stratified clay loam, silt loam, and san loam.
Kokee: KSKE, KSKF	>5	>5	0-42 42	Silty clay loam and silty claySaprolite
Koko: KsB, KsC, KsD	>5	>5	0-48 48	Silt loam and clay loam
Kokokahi: KtC. KTKE	>5	(e)	0-44	Clay or very stony clay
Kolekole: KuB, KuC, KuD		>5	0-38 38-60	Silty clay loam; brittle pan
Kolon: KvB, KvC, KvD	13/2-3/-2	>5	0-20 20	Stony silty clayBedrock.
Kolokolo: Kw. KUL	>5	>5	0–60	Silty clay loam and loam
Koolau: KVSB, KVSE	. >2	2-4	0-32 32-60	Silty clay Clay loam with ironstone bands
Kula: KxC, KxD, KxaD, KxbE	2-5	>5	0-54 54	Loam, silt loam, and silty clay loam Bedrock.
Kunia: KyA, KyB, KyC	>5	>5	0-47 47-74	Silty clay loam
Kunuwein: KZC	>5	>5	0-12 12-60	Very gravelly clay loam
Lahaina: LaA, LaB, LaB3, LaC, LaC3, LaD, LaD3, LaE3.	>5	>5	0-31 31-60	Silty clay loam
Laumaia: LME, LMF, LNE	3}{-5	>5	0-42 42-51 51	Silty clay loam and silt loam Cemented ash and cinders Stratified silt loam and cinders

parties—Co					Corrosivit	у
lassifica- on-Con.	Permeability	Available water	Reaction	Shrink-swell potential	Uncoated steel	Concrete
Unified		capacity			Outcoared see:	
,	Inches per hour 2, 0-6, 3	Inches per inch of soil 0. 10-0. 12	pH salue 6. 1-7. 3	Low	Low	Low.
·	0. 63-2. 0	0. 08-0. 15	6. 6–7. 3	Moderate	Low	Low.
Ŀ	2. 0-6. 3	0. 12-0. 14	6. 6–7. 3	Low	Low	Low.
M	1	0. 12-0. 14	7. 4-7. 8	High	High	Low.
H	0. 06-0. 20		7. 9-8. 4	Low	High	Low.
P TL-CL	6. 3-20. 0 0. 63-2. 0	0. 06-0. 12	6. 1–7. 3	Low	Low	Low.
IL or SM	2, 0-6, 3	0. 09-0. 11	7. 4-8. 4	Low	High	High.
AL OF BAL AL-CL	0. 63-2. 0 0. 63-2. 0	0. 10-0. 12 0. 14-0. 16	6. 6-7. 3 6. 6-7. 3	Low Moderate	Low	Low. Low.
	0. 63-2. 0	0. 15-0. 17	7. 4-7. 8	Moderate	Moderate	Low.
NH	0. 63-6. 3	0, 10-0, 12	6. 1-7. 3	Moderate	Moderate	Low.
ML CL, ML or	2. 0-6. 3 2. 0-6. 3	0. 13-0. 15 0. 12-0. 14	4. 5-6. 0 5. 6-6. 5	Moderate	Moderate	Moderate. Moderate.
SM	2. 0-6. 3	0. 15-0. 17	4. 5–5. 0 4. 5–5. 0		High	High. High.
MT WH WH	2. 0-6. 3 0. 63-2. 0	0. 16-0. 18	6. 6-7. 3	1	_ Low	Low.
CH	0. 06-0. 63	0. 12-0. 14	6. 1-7. 4	High	High	Low.
ML	2, 0-6. 3 0, 63-2. 0	0. 09-0. 11 0. 10-0. 12	4. 0-5. 5 4. 5-6. 0	Moderate	- High	High. High.
ML-MH	2. 0-6. 3	0. 10-0. 12	6. 1–7. 3	Moderate	Low	_ Low.
MH	0. 63–2. 0	0. 12-0. 14	6. 6-7. 3	· 1	High	Low.
MH-OH	6. 3-20. 0 0. 2-0. 63	0. 12-0. 14 0. 12-0. 14	4. 0-5. 0 4. 5-5. 0	Moderate	High	High.
WI	2. 0-6. 3	0. 14-0. 16	6. 1-7. 3	Low	Low	Low.
NL-MH	0. 63-2. 0 0. 63-2. 0	0. 12-0. 14 0. 14-0. 16	4. 0-6. 5 5. 6-6. 6	Moderate Low	Moderate	High. Moderate.
GC MH	2. 0-6. 3 2. 0-6. 3	1:	4. 5-5. 9 4. 5-5.	Low	High	High.
CL-ML	0. 63-2. 0 0. 63-2. 0	0. 10-0. 12 0. 11-0. 13	5. 6-6. 5. 6-6.	Moderate	Low-	Moderate Low.
MH-OH	2. 0-6. 3 . <0.06	0. 15-0. 17	1	8 Moderate	Low	Low.

	Depth	to—	Depth	Classification
Soil scries and map symbols	Bedrock	Seasonal high water table	from surface	Dominant USDA texture
Lawai: LcB, LcC, LcD	Fed >5	Feet (?)	Inches 0-80	Silty day
Leilehun: LeB, LeC.	>5	>5	0–75	Silty clay and clay
Lihue: LhB, LhC, LhD, LhE2, LIB, LIC	>5	>5	0-60	Silty clay; gravelly in places
Lolekaa: LoB, LoC, LoD, LoE, LoF	>5	>5	0-42 42-65	Silty clay
Lualualci: LuA, LuB, LvA, LvB, LPE	>5_	>5	0–60	Clny
Mahana: MaC, MaD, MaD3, MaE, MaE3, McC2, McD2, McE2, MBL.	>5	>5	0-61	Silt loam and silty clay loam
Makaalae: MID, MJD, MWE	2-4	>5	0-40 40	Clay and silty clay
Makalapa: MdB, MdC, MdD	13/2-33/2	>5	0-38 38	Clay Volcanic tuff.
Makapili: MeB, MeC, MeD, MeE	>5	>5	0–60	Silty clay and clay leam
Makawao: MfB, MfC	>5	>5	0-60	Silty clay
Makaweli: MgB. MgC, MgD, MgE2, MhB, MhC, MhD, MhE.	>5	>5	0-60	Silty clay loam and silt loam
Makena: MXC	31⁄2-5	>5	0-44 44	Silt loamAa lava.
Makiki: MkA, MIA	11/2-5	>5	0-54	Clay loam; stony in places
Mala: MmA, MmB	>5	>5	0-40 40-60	Silty ciayCoral sand
Malama: MYD	11/2-21/2	>5	0-8 8-28 28	Extremely stony muck
Mamala: MnC	1-13%	>5	0-19 19	Silty clay loam
Manana: MoB, MoC, MoD2, MpB, MpC, MpD, MpD2, MpE.	>5	>5	0-15 15-15}, 151⁄4-60	Silty clay loam and silty clay PanSilty clay
Mokuleia: Mr, Ms, Mtb	>5	>5	0-16 16-50	Clay loam, loam, or fine sandy loam
Mta	>5	2-4	0-15 15	Clay and clay loam
Molokai: MuA, MuB, MuB3, MuC, MuC3, MuD, MyD3.	>5	>5	0-72	Silty clay loam
Naiwa: NAC, NAC3	3-5	>5	0-52 52-60	Silty clay loam, silt loam, and loam
Niu: NeC, NcD, NcD2, NcE2	_ >5	>5	0-60	Silty clay loam and silty clay
Niulii: NLE, NME		>5	0-40 40	

See footnotes at end of table.

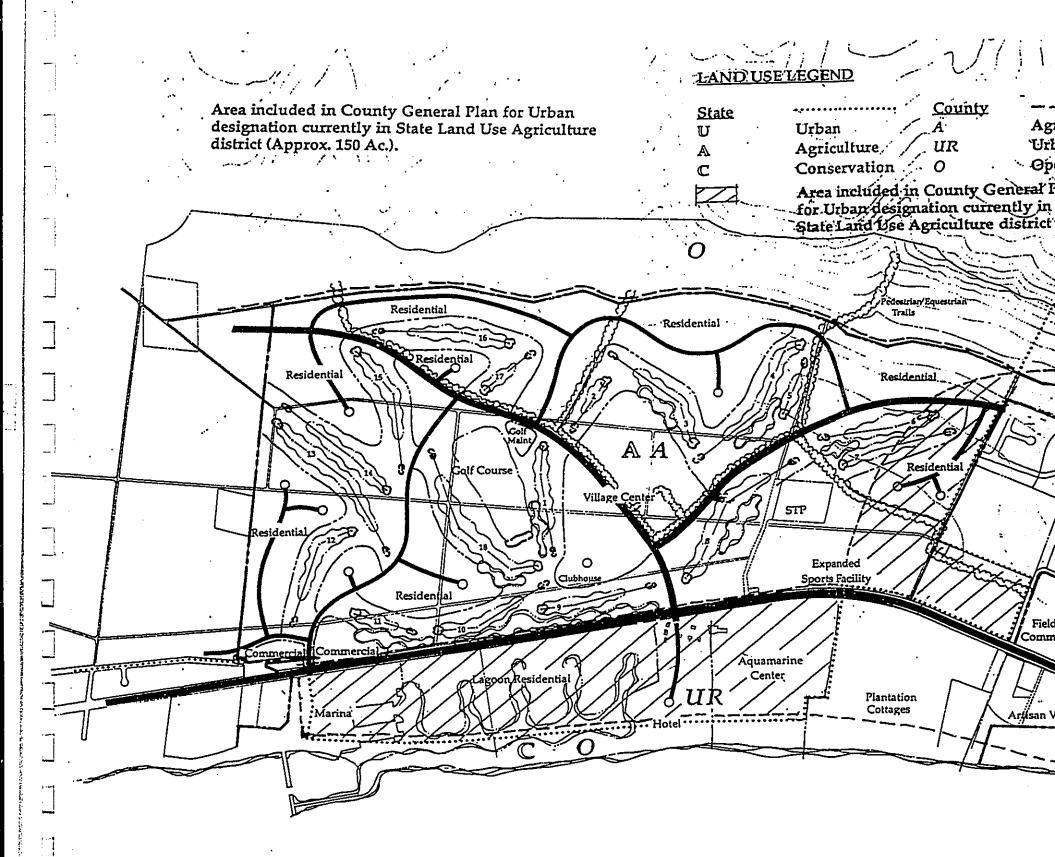
properties—Cor	tinued		1		Corrosivit	у
Classifica- tion—Con.	Permenbility	Available water capacity	Reaction	Shrink-swell potential	Uncoated steel	Concreto
	Inches per hour 0, 63-6, 3	Inches per inch of soil 0. 14-0. 16	pH solue 5. 1-6. 0	Moderate	High	Moderate.
MH	0. 63-6. 3 2. 0-6. 3	0. 10-0. 12	4 0-4 5	Moderate	High	High.
мн-сн	2. 0-6. 3	0. 13-0. 15	5. 1-7. 3	Moderate	Low	Moderate.
WH WH	2. 0-6. 3	0. 10-0. 12 0. 11-0. 13	4. 0-5. 5 4. 0-4. 5	Moderate Low	High	High.
MI-MH	2. 0-6. 3	0. 11-0. 13	5. 6-7. 3	High	Moderate	Low.
CH	0. 06-0. 20 2. 0-6. 3	0. 11-0. 13	5. 6-6. 5	Moderate	High	Moderate.
MH	. 0. 63–2. 0	0, 22	5. 1–6. 5	High	High	Moderate.
CH	0. 05-2. 0	0. 11-0. 13	7. 4-8. 4	High	Moderate	Low.
CH	2, 0-6, 3	0. 12-0. 14	4. 5-5. 5	Low	High	High. Moderate.
МН	2. 0-6. 3	0. 17-0. 19	5. 1–6. 5	Moderate	High	Low.
MH	0. 63-2. 0	0. 14-0. 16	6. 1-7. 3	Low	Low	
ML	2. 0-6. 3	0. 17-0. 19	7. 4-8. 4	Low	Low	Low.
MH	2. 0-6. 3	0. 13-0. 15	5. 1-6. 0	Moderate	_ Moderate	_ Moderate. _ Low.
ML-MH	0. 63-2. 0 6. 3-20. 0	0. 11-0. 13 0. 06-0. 08	6. 1-7. 8 7. 4-7. 8	Moderate	Moderate	Low. Moderate.
SP Pt	≥20. 0 ≥20. 0	0. 10-0. 12	5. 1-6. 0	High shrink, low swell	High	Moderate.
CL-ML	0. 63-2. 0	0. 16-0. 18	6. 6–7. 8	Low	Low	Low.
•	2. 0-6. 3	0. 09-0. 11	4. 5-5. 0		High	High.
MH -MH	- 0. 06 0. 63-2. 0	0. 10-0. 12	4. 0-5. 0	Low	High	
CL or SM	0. 63-6. 3	0. 10-0. 16 0. 06-0. 08	6. 6-7. 3 7. 9-8. 4	Moderate to low	Moderate	Low.
SP	6. 3-20. 0 0. 06-0. 2	0. 12-0. 14	7. 4-7. 8 7. 4-7. 8	High	Moderate	Low.
ML	6. 3-20. 0. 63-2. 0		4. 0-7. 3	, i	Low	Low-
ML	2. 0-6. 3		4. 5-5.	Moderate	High	High.
MH			5. 6-7.	3 Moderate	Low	Low.
ML-CL	0. 63-2. 0			.)	High	High.
MH-OH	2, 0-6, 3	0. 17-0. 19		- L	1	•

	Deptl	to—		Classification
Soil series and map symbols	Bedrock	Seasonal high water table	Depth from surface	Dominant USDA texture
Nobili: Nh	Fed >5	Fed 1}4-3	Inches 0-120	Ciny
Nonopahu: NnC, NoC.	>5	>5	0-65	Clay and silty clay
Oanapuka: OAD, OED	3}4–5	>5	0-46 46-55	Very stony silt loam and loamAa lava.
Olelo: OFC	>5	>5	0–37 37–60	Silty claySaprolite
Oli: OID, OMB, OME, OMF	. 2-4	>5	0-30 30	Silt loamBedrock.
Olinda: ONC, OND, ONE	3–5	>5	0-36 36	Silty clay loam Bedrock.
Olokui: OO E	>5	(1)	4-0 0-11 11-11}£ 11}£-60	Organic matter Silty clay loam Ironstone sheet Saprolite
Opihikao: OPD	<1	>5	0-5 >5	MuckBedrock.
Paniki: PGE, PGF	3–5	>5	0-40 40-50	Silty clay loam and silty claySaprolite.
Paslos: PaC, PbC	>5	>5	0-60	Silty clay and clay
Paia: PcB, PcC, PcC2	>5	>5	0-60	Silty clay and clay
Pakala: PdA, PdC, PHXC,	>5	>5	0–60	Stratified clay loam, very fine sandy loam, silt loam, and silty clay loam; extremely stony in places.
Pamoa: PID, PID2, PJD2	>5	>5	0-62	Silty clay and clay
Pane: PXD	>5	>5	0-39 39-65	Silt loam and loamGravelly loam
Papaa: PYD, PYE, PYF	31⁄4-5	>5	0-28 28-40 40	Clay
Paumalu: PeB, PeC, PeD, PeE, PeF, PZ	>5	>5	0-48 48-70	Silty clayGravelly silty clay
Pauwela: PfB, PfC, PfD	>5	>5	0-54	Clay and silty clay
Pearl Harbor: Ph	>5	1-4	0-31 31-48	ClayMuck
Pohakupu: PkB, PkC	>5	>5	0-76	Silty clay loam
Pooku: PIB, PID, PmB, PmC, PmD, PmE	>5	>5	0-62	Silty clay and silty clay loam
Puhi: PnA, PnB, PnC, PnD, PnE	>5	>5	0-60	Silty clay loam and silty clay
Pulchu: PoB, PoaB, PpA, PpB, PrA, PrB, PsA, PtA, PtB, PuB, PvC.	>5	>5	0-60	Stratified clay loam, loam, loamy sand, fine sandy loam, and silt loam; cobbly or stony in places.
.Puuone: PZUE	114-314	>5	0-20 20-40	SandCemented sand
See footnotes at end of table				

Classifica-					Corrosivity		
Unified	Permeability	Available water capacity	Renction	Shrink-swell potential	Unconted steel	Concrete	
	Inches per hour 0. 20-0. 63	Inches per inch of soil	pH solve 4. 5-7. 8	High,	High	Moderate.	
CH		0. 12-0. 14	7. 4-7. 8	High	Moderate	Low.	
CH	0, 20-0, 63	0. 10-0. 12 0. 08-0. 10	6. 6-7. 8	Low	Low	Low.	
MT	2. 0-6. 3	0. 03-0. 10	0.0-7.6				
MH I	2. 0-6. 3 2. 0-6. 3	0. 10-0. 12	4. 5-5. 0	Moderate Low	High	High.	
MH-ML	2. 0-6. 3	0. 12-0. 14	4. 5-6. 5	Low	High	High.	
мн-он	2. 0-6. 3	0. 13-0. 15	6. 1–6. 5	(2)	High	Low.	
Pt MH-OH	20. 0 2. 0–6. 3	0. 20-0. 30 0. 12-0. 14	4. 0-4. 5 4. 0-5. 0	Moderate-	High	High. High.	
MH	<0.06 · 0.63-2.0			Low	High	High.	
Pt	6. 3–20. 0	0. 20-0. 30	5. 1-6. 5	High,	High	Moderate.	
мн	2. 0–6. 3	0. 17-0. 19	4. 5-6. 0	Moderate	High	Moderate.	
MH .	2, 0-6, 3	0. 10-0. 12	4, 5–5. 5	Low	High	High.	
MH	0. 63-2. 0	0. 13-0. 15	7. 4-7. 8	Low	Low	Low.	
CL and ML	0. 63-2. 0	0. 08-0. 14	4. 5–6. 0	Low	Low	Moderate.	
CL	0. 20–0. 63	0. 09-0. 11	4. 5-7. 3	High	Low to moderate	Low to mode	
MH SM or GM	2. 0–6. 3 2. 0–6. 3	0. 14-0. 16 0. 03-0. 10	6. 1-7. 3 6. 6-7. 3	Moderate Low	Moderate	Low. Low.	
CH C	0. 06-0. 20 0. 20-0. 63	0. 10-0. 12 0. 11-0. 13	6. 1-6. 5 6. 1-6. 5	High Moderate	Moderate	Low. Low.	
MH CL	2. 0–6. 3 2. 0–6. 3	0. 10-0. 12 0. 07-0. 09	4. 5–6. 0 5. 5–6. 0	Moderate Low	High High	High. Moderate.	
MH	2. 0-6. 3	0. 10-0. 12	4. 0-5. 0	Low	High	High.	
CH Et	<0.06 <0.06	0. 10-0. 12 0. 16-0. 18	6. 6-8. 4 7. 4-7. 8	High, High,	High High	High. High.	
MH	2. 0-6. 3	0. 12-0. 14	6. 1-6. 5	Moderate	Moderate	Low.	
ATH.	2. 0-6. 3		4. 0∸6. 0	Low	High	High.	
MH	2.0-6.3	0. 10-0. 12	4. 5-6. 5	Moderate to low	High	Moderate.	
	0, 63-2, 0	0. 09-0. 13	6. 6-7. 8	Moderate to low	Low	Low.	
CL, SM or ML	U. D3-2, U	U. 05-0. XU	2. 2 3			_	
iP	6. 3–20. 0 < 0. 06	0. 06-0. 08	7. 9-8. 4	Low	Low	Low.	

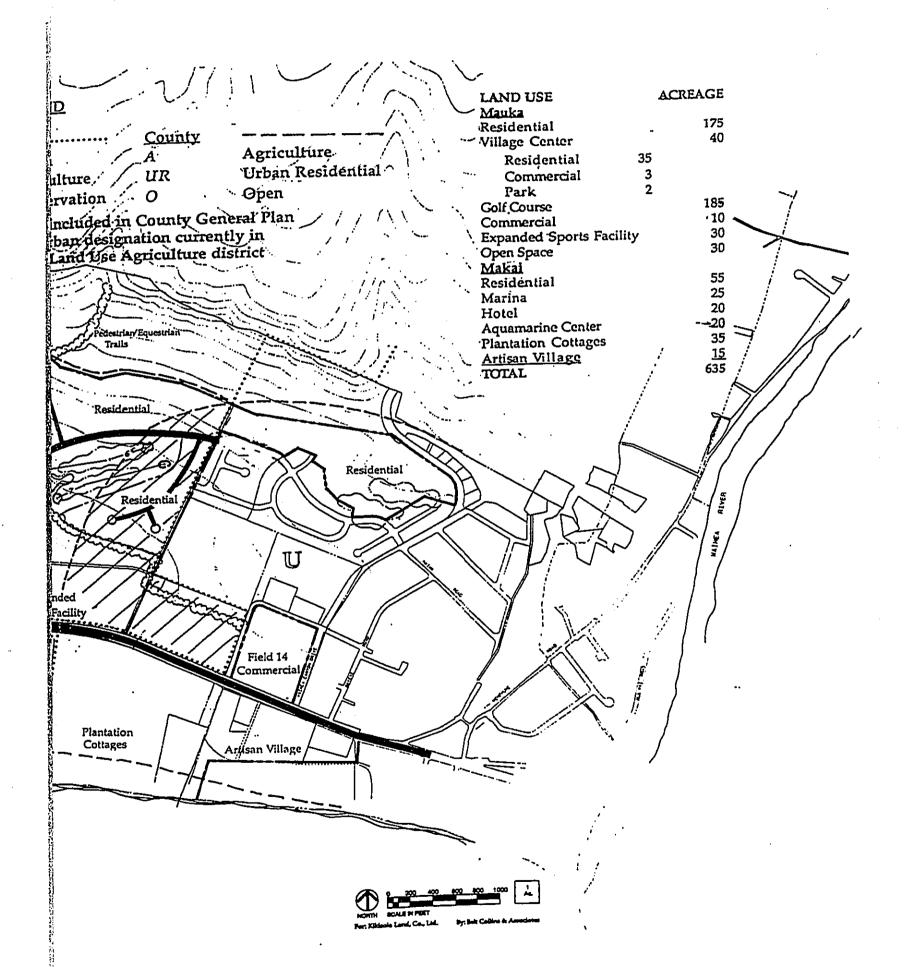
APPENDIX C

ENGINEERING STUDY FOR KIKIAOLA MASTER PLAN BY BELT COLLINS & ASSOCIATES DATED JULY 26, 1990



Kikiaola Master Plan

Kikiaola, Waimea, Kauai, Hawaii



ENGINEERING STUDY FOR KIKIAOLA MASTER PLAN

Prepared for

Kikiaola Land Co., Ltd.

by

Belt Collins & Associates

July 24, 1990

(Revised July 26, 1990)

Revision No. 1 for Engineering Study for Kikiaola Master Plan

July 26, 1990

NOTICE TO ALL CONCERNED: The following items below constitute revisions to the Engineering Study for Kikiaola Master Plan, issued July 24, 1990.

1. Section 3.2, Drainage, has been replaced with a revised section. The second to the last sentence of the section has been revised to read as follows (note: changes are highlighted):

"Assuming that the existing reservoir is deepened to a maximum bottom depth of 25 feet, with side slopes of 2.5H:1V, runoff/routing computations performed via the U.S. Army Corps of Engineers HEC-1 program show that roughly 245 cfs of (peak) runoff could be retarded by the reservoir."

 The HEC-1 input/output contained in Appendix A has been replaced with revised input/output.

1. INTRODUCTION

This report provides a preliminary evaluation of the engineering requirements for the planned Kikiaola development in Waimea, Kauai, Hawaii.

GENERAL SITE DESCRIPTION

2.1 Location and Size

The planned Kikiaola development is located immediately west of and adjacent to the town of Waimea, on the southwestern portion of the island of Kauai. It is comprised of an approximately 840-acre parcel, which straddles Kaumualii Highway as it runs from the ocean inland to roughly the 50-ft elevation. The parcel ends at its western boundary along a line running inland of Kikiaola Harbor. The town of Kekaha lies to the west of the development.

2.2 Climate

The Waimea-Kekaha region is generally warm and dry, with an average temperature of approximately 75°F and mean annual rainfall of 20 inches or less. Gentle tradewinds prevail in this area.

2.3 Topography

The Kikiaola development lies on part of the Mana Plain, which is characterized by generally flat slopes near the shore which rise rather abruptly around the 50-foot elevation.

2.4 Soils

Soils in the area of the Kikiaola development are generally Entisols, which are typically characterized by weakly developed soils found on old beach sand and on recent alluvial deposits.

3. INFRASTRUCTURE

3.1 Roadways

The two-lane, Kaumualii Highway is the principal thoroughfare running through the Kikiaola development area and connecting the towns of Waimea and Kekaha.

There will be four major roadway intersections with Kaumualii Highway for the development. One of the intersections is a "cross" intersection with approaching roads on opposite sides of the highway and positioned directly across from each other. The other three intersections are "tee" intersections. Based on discussion with the State Department of Transportation (DOT), the three intersections will require full channelization. All intersections will need left turn pockets within the highway. Acceleration/deceleration lanes will be needed on both sides of the highway for the cross intersection, and on the appropriate side of the highway for the tee intersections. The intersections will be positioned at least 1,200 feet apart, per DOT requirements.

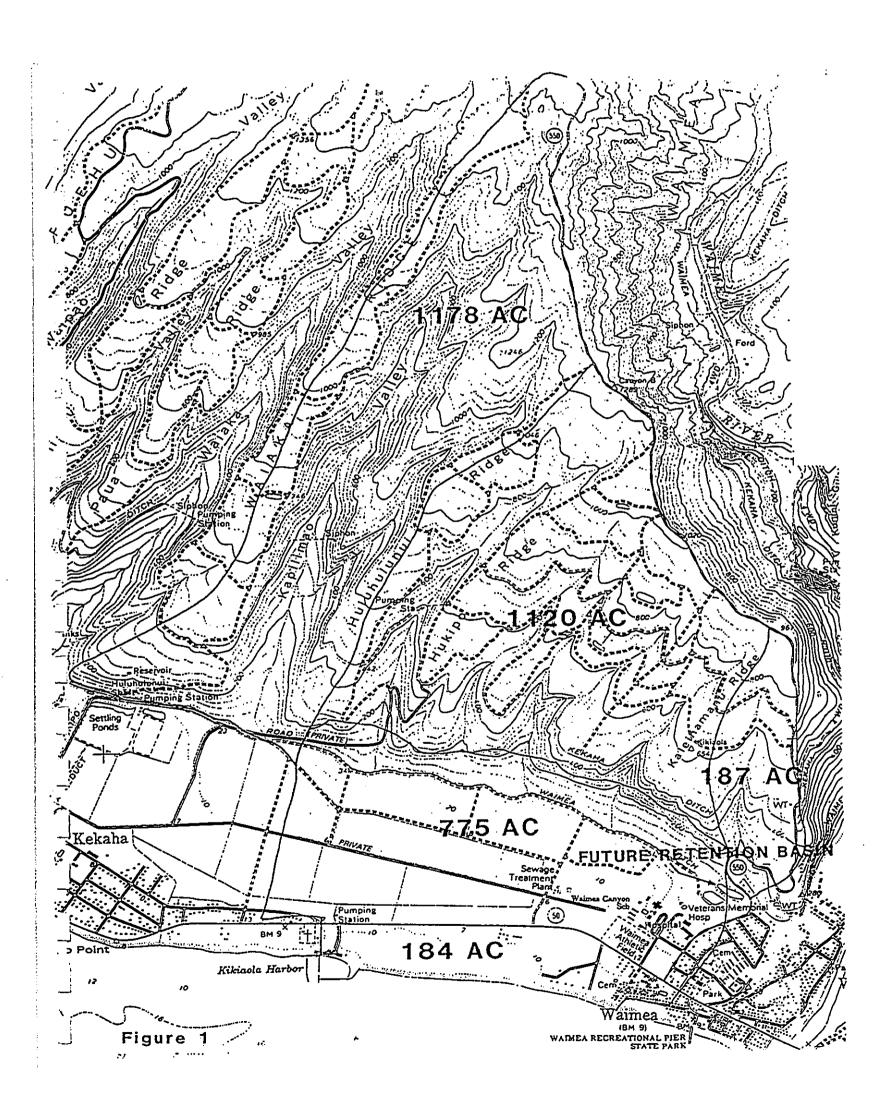
3.2 Drainage

Presently, large amounts of storm water runoff flow from the steep hillsides mauka of the project site and into the canefields below. A large portion of this runoff is intercepted by a network of irrigation ditches, which eventually convene into a single culvert draining into Kikiaola Boat Harbor.

The total area of the watershed above the Kauamualii Highway is approximately 3,260 acres (refer to Figure 1). This watershed area can be expected to generate runoff at a rate of nearly 14,000 cubic feet per second (cfs) for a 100-year storm without retention measures. (Note: The portion of the development makai of Kaumualii Highway is expected to drain directly into the ocean, and is therefore not included in the runoff calculation.)

Because of the high runoff volume that will be encountered, it appears that the most feasible approach to drainage will be to utilize a large portion of the new golf course as a sump, to contain and retard runoff during heavy rains. This stored runoff would then be routed to a box culvert that will take the water from the mauka side of Kaumualii highway, under the highway, and to a drainage ditch discharging into the ocean at the boat harbor.

Even with the preceding measures, the magnitude of the runoff generated is such that use of the golf course as a sump will not significantly reduce the peak flow at the highway. It will be desirable to continue using an existing reservoir, located mauka of Veteran's Memorial Hospital (refer to Figure 1), as a retention basin to retard runoff coming from the 187-acre sub-basin which has Kaleinamanu Ridge as its western boundary. The estimated runoff from this sub-basin is expected to be approximately 890 cfs. Assuming that the existing reservoir is deepened to a maximum bottom depth of 25 feet, with side slopes of 2.5H:1V, runoff/routing computations performed via the U.S. Army Corps of Engineers HEC-1 program show that roughly 245 cfs of (peak) runoff could be retarded by the reservoir. Although this amount is relatively small in relation to the total runoff expected, it is significant enough to justify maintaining use of the reservoir as a retention basin.



The existing Waimea Water System taps three primary sources: Waimea Shaft 9 (at elevation 40 feet on the west bank of the Waimea River), supplying 450 gallons per minute (gpm), Waimea Well 26 (at elevation 180 feet above Waimea town), supplying 220 gpm, and Waimea Deepwell 2 (at elevation 115 feet above Waimea town), supplying 210 gpm. Water from these sources is piped to a single 0.25-million gallon (MG) tank at the 180-foot level above Waimea town. A portion of the water from this reservoir is pumped to a 0.1-MG tank at the 525-foot elevation which serves the Waimea Heights residential subdivision.

The existing Waimea system is presently operating near capacity. This means that the bulk of the water demand projected for the Kikiaola development will have to be satisfied through the development of new well and reservoir improvements to the existing water distribution system. According to the Department of Water (DOW), there may be several hundred units of water allocation still available. It may therefore be possible for one of the smaller hotel or development phases to be built prior to any major improvements to the existing water system.

For its domestic water system, water demand for the entire Kikiaola project is estimated at close to 1.5 million gallons per day (MGD) (refer to calculations in Appendix B). Assuming that the existing Waimea system cannot be relied upon for any significant contributions toward meeting this demand, it is estimated that 13 new well sources, each with a capacity of 200 gallons per minute (gpm), will have to be developed (refer to calculations in Appendix C). The capacity of 200 gpm per well is based on current well yields in the Waimea area. The elevations of the existing Waimea Deepwell 2 (115 feet) and Waimea Well 26 (180 feet) provide some indication of the elevations that may be required for positioning of the new wells, however an in-depth hydologic study would be needed to accurately determine this.

Approximately 2.2 million gallons (MG) of total additional reservoir capacity would also be needed to provide storage and maintain sufficient pressure throughout the distribution system (refer to calculations in Appendix D). This capacity could be provided through two 1-MG reservoirs and one 0.2-MG reservoir, located near the 180-foot elevation. The well and reservoir improvements would only accommodate the new Kikiaola development, and would not be available for use by Waimea town.

The planned golf course for the Kikiaola development is expected to require large amounts of water for irrigation. This need could be satisfied by re-use of treated effluent from the Waimea Wastewater Treatment Plant (WWTP). In this manner, the high-quality basal water tapped from well sources would be reserved for the development's domestic needs. Other potential sources of water are the Kekaha and Waimea irrigation ditches, and brackish groundwater

sources. A system using a blend of the aforementioned sources, including the re-used effluent, could be developed to supply the golf course's irrigation requirements.

3.4 Sewer

The existing Waimea WWTP currently processes wastewater flows generated by the Waimea town area. The plant provides secondary treatment of wastes by employing an activated sludge process. It has a capacity of 0.3 MGD, although average flow is currently on the order of 0.2 MGD. The remaining capacity above current average flow (0.1 MGD) has been committed by the County to the present Waimea town area. Thus, any new development will require expansion of the WWTP facilities.

The Kikiaola project is expected to generate an average wastewater flow of roughly 1.2 MGD. To handle this sewage, one option would be to expand the capacity of the Waimea WWTP to 1.5 MGD. Plant modifications would involve the construction of additional units for the existing treatment processes, including the aeration tanks, final settling tanks, chlorine contact tank, aerated sludge holding tank, and sludge drying beds. The magnitude of the required expansion in treatment capacity suggests that the addition of new units, rather than the enlargement of the existing treatment units, would be more feasible.

The Waimea WWTP currently occupies an area of about 4 acres. The additional area needed for the plant upgrade is estimated at 10 acres, bringing the total plant area to 14 acres. A significant portion of plant area will be needed for injection wells, which would be used as the required backup disposal system for the treated effluent per Department of Health (DOH) regulations. The wells would be utilized to prevent overflow if the golf course irrigation system was inoperable or unable to handle the effluent.

Although the existing treatment plant is at a relatively low elevation (7-10 feet), much of the new development will be at or below this elevation. At least one pump station, and probably several, will therefore be required to transport sewage to the plant.

Another option to handle the wastewater generated from the Kikiaola development would be to construct a new WWTP facility on State land to the west of the development, on the opposite side of the adjoining Knudsen property. Because this plant would be built on State land, it is likely that the State and County would require that the plant accommodate wastewater from Kekaha town in addition to that generated by the Kikiaola project. Kekaha currently relies on disposal via cesspools and septic tanks, but Since Kekaha's average wastewater flow is estimated to be on the order of 0.326 MGD (refer to Appendix F), a total plant capacity of approximately 1.5 MGD would be required.

This plant, which would operate using an activated sludge procedure, would require a total area of approximately 14 acres. As in the Waimea WWTP

upgrade option, a significant portion of the area would be devoted to an injection well backup system for effluent disposal.

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 Lyon Associates, Inc. 1970. Brief Soil Descriptions. Island of Oahu.
- Morris, H.M. and J.M. Wiggert. 1972. Applied Hydraulics in Engineering.
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APPENDIX A

HEC-1 Analysis

The U.S. Army Corps of Engineers HEC-1 Flood Hydrograph Package was used to analyze runoff from the 187-acre sub-basin, located to the northeast of the development, which has Kaleinamanu Ridge as its western boundary.

A 20-foot long spillway was assumed to be located 10 feet below the top of the reservoir. This would serve to provide a controlled release of the accumulated runoff.

Input/output from the computer run are provided on the pages which follow.

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985 U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

HEC-1 INPUT

PAGE 1

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10......7....8.....9.....10
LINE
              100-YEAR RUNOFF ANALYSIS FOR KIKIAOLA DEVELOPMENT
           ID
              FILE "KIKI-1"
           ID
                                   288
                            1200
                 5 1JAN89
           IT
           10
                 10 RUNOFF CALCULATION FOR 187-ACRE SUB-BASIN
           KK
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  6
                             0.93 1.80 3.25
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           PH
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FLOOD HYDROGRAPH PACKAGE HEC-1 (18H XT 512K VERSION) -FEB 1,1985 U.S. ARMY CORPS OF ENGINEERS, THE HYPROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

> 100-YEAR RUNOFF ANALYSIS FOR KIKLAOLA DEVELOPHENT FILE "KIKI-1"

10

OUTPUT CONTROL VARIABLES

SE

ZZ

15

4 PRINT CONTROL IPRNT O PLOT CONTROL IPLOT O. HYDROGRAPH PLOT SCALE QSCAL

5

HYDROGRAPH TIME DATA

5 MINUTES IN COMPUTATION INTERVAL NHIN 1JAN89 STARTING DATE

IDATE 1200 STARTING TIME ITIME

288 NUMBER OF HYDROGRAPH ORDINATES

NO

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2JAN89 ENDING DATE
                   NDDATE
                   MOTIME
                               1155 ENDING TIME
                                      .08 HOURS
                 COMPUTATION INTERVAL
                     TOTAL TIME BASE 23.92 HOURS
         ENGLISH UNITS
                            RUNOFF CALCULATION FOR 187-ACRE SUB-BASIN
             SUBBASIN RUNOFF DATA
               SUBBASIN CHARACTERISTICS .
                              .29 SUBBASIN AREA
                    TAREA
               PRECIPITATION DATA
                                   DEPTHS FOR O-PERCENT HYPOTHETICAL STORM
                                    ..... TP-40 ..... TP-49 .....
                ..... HYDRO-35 .....
                                                   6-HR 12-HR 24-HR 2-DAY 4-DAY 7-DAY 10-DAY
               5-MIN 15-MIN 60-MIN
                                    2-HR 3-HR
                                   .4.50
                                           5.50
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                 ..93 1.80 3.25
                                             STORM AREA =
                                                          .29
             . SCS LOSS RATE
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                                 .19 LAG
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ARNING *** TIME INTERVAL IS GREATER THAN .29*LAG
                                                   UNIT HYDROGRAPH
                                              13 END-OF-PERIOD ORDINATES
                                                       134. 74.
                                                 236.
                       508.
                               598.
              158.
                                 2.
                             ROUTE INTO DEEPENED RESERVOIR #1
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HYDROGRAPH ROUTING DATA

. :11 RS	STORAGE	ROUTING								
		ISTPS	1	NUMBER OF	SUBREACHES	5				
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I		×	.00 W	ORKING R	ND D COEFI	CLENT				
12 SV	STORA	AGE	.0	6.7	15.3	33.9	37.9	52.0		
13 SE	ELEVAT	ION	-00	5.00	10.00	15.00	20.00	25.00		
14 50	DISCHA	RGE	0.	0.	0.	0.	0.	901.		
15 SE	ELEVAT	ION	-00	5.00	10.00	15.00	20.00	25.00		
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	соня				MPUTED STORAGE-OUTFLOW-ELEVATION DATA					
	STORAGE	-00	6.70	15.30	33.90	37.90	52.00			
·).	OUTFLOW	.00	.00	.00	.00	-00	901.00			
	ELEVATION	.00	5.00	10.00	15.00	20.00	25.00			
1		RUNOFF SINNARY								

FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE HILES

		PEAK	TIME OF		LOW FOR MAXIM	SUM PERIOD	BASIN AREA	MAXIMUM STAGE	TIME OF
OPERATION :	STATION	FLOW	PEAK -	6-HOUR	24-HOUR	72-HOUR	Anca	Sinds	
HYDROGRAPH AT	10	1049.	12.17	205.	79.	79.	.29		
ROUTED TO	20	804.	12.25	190.	59.	59.	.29	24.46	12.25

NORMAL END OF HEC-1 ***

APPENDIX B

Daily Water Demand and Wastewater Flow Calculations

Average daily water demand was calculated by applying domestic water consumption guidelines to data on use and acreage/number of units (whichever was applicable) for the individual development parcels.

The calculations for water demand were based on information and procedures specified in *Water System Standards* (Dept. of Water, County of Kauai, 1985), unless otherwise noted.

Wastewater flow generation rates were generally estimated at 80 percent of the calculated water demand rates, with a few exceptions as noted.

The calculations are summarized in table form on the following pages.

Table B-1. Water Demand and Wastewater Flow Calculations.

	MGD		= = :		
VAGE TON	0.042 0.031 0.086 0.070 0.037 0.029	0.035 0.032 0.070 0.058	0.074	0.058 0.015 0.019	0.039 0.057 0.075 0.087 0.087
DAILY SEWAGE GENERATION TE TOTA					
DAIL GEN RATE	8/U 8/Ac 8/U 8/U 8/U	8/Ac g/U	2,400 g/Ac 2,400 g/Ac	g/Ac	<u> </u>
≃	280 2,400 400 2,400 2,400 2,80	2,400	2,400	2,400 2,400	= = = =
,a	MGD	= = = =	= = =		= = = =
DAILY WATER CONSUMPTION ATE TOTAL	0.053 0.039 0.108 0.088 0.046 0.036	0.044 0.087 0.072	0.093	0.072	0.049 0.071 0.094 0.109 0.016
WA.					
AILY	8/U 8/U 8/U 8/U 8/Ac	3,000 g/Ac 500 g/U	g/Ac g/Ac	8/U 8/Ac 9/11)
	350 3,000 350 350 3,000 3,000 350	3,000	3,000	3,000,000	
NO. OF UNITS			;	. 10 . 00)
25	150 216 250 250 130	9 1 8 71 41 44 44 44 44 44 44 44 44 44 44 44 44	111 2	55 	28 142 188 218 32
AREA (Ac)	23.5 10.5 13.5 15.2 15.2 12.3 12.3 12.3 13.3 13.3 13.3 13.3 13	14.5 20 43.5 36	31 205 49 49	5 ~ ~ <i>€</i>	24.5 35.5 47 54.5 8
	,	•	(R)]		
USE	R)]	(C/R)	C/R) /C(C	(C/R)	
/ N	RT] (R,Y)] (R,Y) (R,Y) (Center	an Village/C((20 Ac)/R-4 (43.5 Ac)/R-4 (36 Ac)/R-4	ty/C((House re	-12] ire/C /R-4	Ac)/R-4 Ac)/R-4 (c)/R-4 Ac)/R-4 (c)/R-4
IPTIC	RESO //C(C, C, C	an Village/C (20 Ac)/R-4 (43.5 Ac)/R-4 (36 Ac)/R-4	Facility ourse lub F	R-10-R-12] 1ge Square/(22 Ac)/R-4	15 Ac 55 Ac 7 Ac)/ 15 Ac Ac)/F
DESCRIPTION / USE	Marina [Hotel/RESORT] [Marina/C(C/R)] R-4 (54 Ac)/R-4 Hotel/RESORT Aquamarine Center [Condos/] [Commercial/C(C/R)] Plantation Cott./RESORT	Artisan Village/C(C/R) R-4 (20 Ac)/R-4 R-4 (43.5 Ac)/R-4 R-4 (36 Ac)/R-4	Sports Facility/C(C/R) Golf Course [Golf Club House/C(C/R)] Village Square	<u> </u>	
	· · · · ·	Arti R-4 R-4	% Q \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	ZENE Z	**************************************
NO.	BD2100BA14.	35H H	4 2 2 2 2 2 4 4 4 4 4 4 4 4 4 4 4 4 4 4	86%	860112

Table B-1. Water Demand and Wastewater Flow Calculations. (cont.)

		•
	DAILY SEWAGE GENERATION TOTAL	0.052 MGD 0.066 " 0.012 " 0.014 " 0.023 "
	DAILY (GENER RATE	280 " 2,400 g/Ac
	ATER PTION TOTAL	G
••	DAILY WATER CONSUMPTION RATE	500 g/U 350 " 3,000 g/Ac
	NO. OF UNITS	130 164 44 1 + 49
	AREA (Ac)	32.5 41 4 4.5 4.5 9.5 (4.0)
	LOT DESCRIPTION / USE NO.	R-4 (32.5 Ac)/R-4 R-4 (41 Ac)/R-4 MF Condos/R-10-R-12 MF Condos/R-10-R-12 Commercial/C(C/R) Commercial/(C/R)
	LOT NO.	13 14 16 17 18

1.167 MGD 1.459 MGD 836.7 Ac *TOTAL*

APPENDIX C

Pump Capacity Calculations for Domestic Water System

The following pump capacity calculations for the domestic water system were based on information and procedures specified in *Water System Standards* (Dept. of Water, County of Kauai, 1985), unless otherwise noted.

From Table 18, the relevant criterion is as follows:

Criterion "4":

Meet maximum day demand with an operating time of 16 hours.

(The largest pumping unit shall be considered out of service (stand-by).

 $Q_{MAX} = 2.189 \text{ MGD}$

$$Q_{\text{FUMP-REQD}} = Q_{\text{MAX}} \times (24/16)$$

= 2.189 x (24/16)
= 3.284 MGD
= 2,280 gpm say 2,300 gpm

The existing wells of the Waimea Water System typically have yields of approximately 200 gpm. For simplicity, it will be therefore be assumed that the pumps needed for the Kikiaola project will be uniform in size, with capacities of 200 gpm each.

CAPACITY_{FUMP} = 200 gpm

The initial estimate of the number of pumps required is:

(NO. OF PUMPS REQ'D), =
$$Q_{PUMP-REOTD}/CAPACITY_{PUMP}$$

= 2,300/200
= 11.5 say 12 pumps

However, per Criterion "4," a stand-by pump of maximum size will also be needed. The final number of pumps required will therefore be:

APPENDIX D

Reservoir Capacity Calculations for Domestic Water System

The following reservoir capacity calculations for the domestic water system were based on information and procedures specified in *Water System Standards* (Dept. of Water, County of Kauai, 1985), unless otherwise noted.

The required reservoir capacity is found by performing calculations on the bases of two criteria, and using the larger value determined.

Criterion "a":

Meet maximum day consumption. Reservoir full at the beginning of the 24-hr period with no source input to the reservoir.

 $Q_{AVE} = 1.459 \text{ MGD}$

From Table 17,

Max. Daily Demand Factor = 1.5

 $Q_{MAX} = Q_{AVE} \times 1.5$ = 1.459 x 1.5 = 2.189 MGD

Therefore,

 $VOL_{REQID-a} = 2.189 \text{ MG}$ say 2.2 MG

Criterion "b":

Meet maximum day rate plus fire flow for duration of fire. Reservoir 3/4 full at start of fire, with credit for incoming flow from pumps, one maximum size pump out of service.

(refer to pump calculations)

From Table 16, fire flow requirement is 2,000 gpm for 2 hr.

 $Q_{MAX} = 2.189 \text{ MGD}$

 $Q_{FIRE} = 2,000 \text{ gpm}$ = 2.88 MGD

t = 2 hr= 0.083 d

Then,

 $(Q_{MAX} \times t) + (Q_{FIRE} \times t) = (3/4 \times VOL_{REOTD-b}) + (Q_{FUMF} \times t)$ $(2.189 \times 0.083) + (2.88 \times 0.083) = (3/4 \times VOL_{REOTD-b}) + (3.284 \times 0.083)$ $VOL_{REOTD-b} = 0.198 \text{ MG}$ say 0.20 MG

Since $VOL_{REQD-8} > VOL_{REQD-8}$,

VOLREOD = 2.2 MG use two 1-MG reservoirs and one 0.2-MG reservoir

APPENDIX E

Domestic Water System Capacity Calculations

The following pump capacity calculations for the domestic water system were based on information and procedures specified in *Water System Standards* (Dept. of Water, County of Kauai, 1985), unless otherwise noted.

For the water distribution system as a whole, the following conditions are required:

The capacity of the distribution system shall deliver the maximum daily demand simultaneously with the required fire flow.

The distribution system shall also deliver the peak hour flow (without fire flow).

Therefore, based on the first of the above criteria:

$$Q_{\text{SYSTEM-}1} = Q_{\text{MAX}} + Q_{\text{FIRE}} = 2.189 + 2.88 = 5.069 \text{ MGD}$$

For the second criterion:

 $Q_{SYSTEM-2} = Q_{PEAK HR}$

From Table 17, the demand factor for peak hour flow is:

Peak Hour Demand Factor = 3.0

 $Q_{\text{SYSTEM-2}}$ = (Peak Hour Demand Hour Factor) x Q_{AVE} = 3.0 x 1.459 = 4.377 MGD

Since Q_{SYSTEM-1} > Q_{SYSTEM-2} Q_{SYSTEM-1} governs, and

 $Q_{\text{SYSTEM}} = 5.069 \text{ MGD}$ say 5.1 MGD

APPENDIX F

Wastewater Flow Calculations

The following wastewater flow calculations for the sewer system were based on information and procedures specified in Design Standards of the Division of Wastewater Management (Dept. of Public Works, City & County of Honolulu, 1984), unless otherwise noted.

From calculations in Appendix B, the average wastewater flow for the new development is estimated at 1.167 MGD.

 $Q_{AVE} = 1.167 \text{ MGD}$

The maximum wastewater flow can be estimated by multiplying the average flow by a flow factor. This flow factor is based on Babbit's Formula, and requires an estimate of the population.

To estimate the population for the new development, the project site was broken up into three major categories of land use. Typical population densities for each type of land use were then applied to these categories, either on a capita per acre (cpa) basis or on a capita per home/unit basis.

CATEGORY	AREA (Ac)	NO. OF HO UNITS	MES/ POPULATION · DENSITY	· TOTAL POPULATION
	(120)		4 cpu	8,392
Residential	481	2,098	-	3,860
Commercial	96.5		40 cpa	·
Resort	58.2	459	3 cpu	1,377
			TOTA	L 13,629

Therefore, the population (in thousands) is approximately:

P = 13.6

From Babbit's Formula, the maximum flow factor is:

MFF =
$$5/P^{02}$$

= $5/(13.6)^{02}$
= 2.97

The maximum flow is then:

 $Q_{MAX} = Q_{AVE} x MFF$ = 1.167 x 2.97 = 3.47 MGD

It should be noted that the groundwater table in the low-lying beach and town area of Waimea has been known to result in cesspool and septic tank overflows during periods of heavy rainfall. This condition can also be expected to cause significant infiltration/inflow contributions to the wastewater flow.

Kekaha Wastewater Flow Calculations

The wastewater flow generated by the town of Kekaha can be estimated by assuming a wastewater flow generation rate of 100 gpcd.

According to The State of Hawaii Data Book 1989 (DBED, 1989), the population of Kekaha in 1980 was 3,260 persons.

The average wastewater flow from Kekaha can therefore be estimated as:

 $Q_{\text{XEKAHA}} = 3,260 \times 100$ = 0.326 MGD

APPENDIX D

LETTER FROM U.S. ENVIRONMENTAL PROTECTION AGENCY TO THE HAWAII DEPARTMENT OF HEALTH DATED OCTOBER 4, 1993



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY REGION IX

75 Hawthorne Street
San Francisco, Ca. 94105-3901
Mail Code: W-6-2

DCT 4 1993

Bill Wong, Branch Chief Safe Drinking Water Branch State Department of Health P.O. Box 3378 Honolulu, Hawaii 96801

Dear Mr. Wong:

Thank you for sending us a copy of the draft Waimea Wastewater Treatment Plant Effluent Reuse/Disposal Alternative Study prepared for the County of Kauai by Austin, Tsutsumi & Associates, Inc. Your staff requested our comments on the UIC paragraph of the August .25, 1993 letter from Kiyoji Masaki, Chief Engineer for County of Kauai, to Pete Madrigal of the HDOH Wastewater Branch regarding the formentioned study. Nutrient removal would not be necessary if certain conditions are met. Our comments are as follows:

- If injection is into an aquifer that has greater than 10,000 mg/l total dissolved solids, then injection is not into an underground source of drinking water (USDW) and drinking water standards do not apply.
- If injection is into a USDW or the injectate migrates into a USDW, then EPA could require the injectate to meet maximum contaminant levels (MCLs).
- Should an injection well be approved and surface water quality problems develop, such as algal blooms, EPA may request studies to determine if effluent from the injection wells is reaching the ocean. If it is shown that effluent is entering the ocean, then the injectate would be subject to surface water standards.

EPA strongly supports reclamation of treated wastewater, especially in Hawaii where water is a valuable and limited resource. I appreciate the reclamation that has occurred due to the cooperative efforts of the County of Kauai and Kekaha Sugar.

The County of Kauai has requested a federal UIC permit application and we will be sending one to them. Once we have a completed application from the County, we will then be able to make a determination on the suitability of the injection wells and what standards would apply to the injectate if the wells are approved.

Thank you for soliciting our input. If you have any questions, please do not hesitate to call me at (415) 744-1835 or Luisa Valiela of my staff at (415) 744-1842.

Sincerely,

Daris Better

Doris Betuel, Acting Chief Groundwater Pollution Control Section

cc: Edmond Renaud, County of Kauai Doug Haigh, County of Kauai Pete Madrigal, Wastewater Branch, HDOH Harold Eichelberger, HDOH, Kauai

APPENDIX E

CORRESPONDENCE BETWEEN
AUSTIN, TSUTSUMI & ASSOCIATES, INC. AND
HAWAII DEPARTMENT OF HEALTH

TED S. KAWAHIGASHI, P.E. GEORGE M. NEUFFER, P.E. KENNETH K. KUROKAWA, P.E. THOMAS S. OTAGURO IVAN K. NAKATSUKA, P.E.

#0-93-104

January 24, 1994



Mr. Dennis Tulang, Chief Wastewater Branch Department of Health State of Hawaii P.O. Box 3378 Honolulu, Hawaii 96801

Dear Mr. Tulang:

Subject: Walmea Wastewater Treatment Plant (WWTP)

Effluent Reuse/Disposal Alternative Study, Walmea, Kauai

We are currently finalizing the subject report — the June 25, 1993 draft which was transmitted to the Department of Health (DOH) by Kauai County. The County has requested that we confirm in writing the following statements in our report, which were based on my discussions with you:

"Based on discussions with DOH's Wastewater Branch (which regulates Chapter 62), it was determined that the following DOH requirements would apply to an injection well(s) as a backup to a DOH-approved reuse system:

- No injection wells are required if the reuse system has a reclaimed water reservoir as a backup. The capacity of such a reservoir must conform to DOH's guidelines for reuse of reclaimed water.
- A single injection well capable of accommodating the peak flow is sufficient as a backup to the reuse system, in lieu of a backup reclaimed water reservoir."

I would also like to take this opportunity to confirm that the peak flow to be accommodated by injection wells can be significantly less than what would be calculated using the Babbit formula, if documented by historical flow records and/or equalized prior to injection. Application of the former would be based on the highest day's flow over the past several years, as compared to the current average daily flow. Application of the latter would involve construction of an effluent equalization reservoir to retain the effluent and discharge to the well(s) at a controlled rate approximating the average daily flow.

ATA

AUSTIN, TSUTSUMI & ASSOCIATES, INC.

Department of Health Mr. Dennis Tulang, Chief

January 24, 1994

Thank you for your attention in responding to these matters. Please feel free to call me at 533-3646 should you have any questions.

Sincerely,

AUSTIN, TSUTSUMI & ASSOCIATES, INC.

Вv

IKN:MAF

IVAN K. NAKATSUKA, P.E. Assistant Vice President and Chief Environmental Engineer

ce: Harry Funamura, Kauai County

JOHN WAIHEE



STATE OF HAWAII

DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

In reply, please refer to:

JOHN C. LEWIN, M.D. DIRECTOR OF HEALTH

EMD / WB

9400112 PM1:VKAUAIWAIMEA.ATA

February 24, 1994

Mr. Ivan K. Nakatsuka, P.E. Asst. Vice President and Chief Environmental Engineer Austin, Tsutsumi & Associates, Inc. 501 Sumner Street, Suite 521 Honolulu, HI 96817-5031 FEB 2 8 1994

AUSTIN, TAUTSUMI & ASSOCIATES, INC.
Honolulu, Howoii 96817-5031

Dear Mr. Nakatsuka:

Subject:

WAIMEA WASTEWATER TREATMENT PLANT (WWTP)

EFFLUENT REUSE/DISPOSAL ALTERNATIVE STUDY

WAIMEA, KAUAI

The Department of Health (DOH) received your letter dated January 24, 1994 requesting to confirm the statements in your report to the County of Kauai about the subject project.

The design peak flow should follow the requirements stated in the Design Standards, Department of Public Works, County of Kauai. This design peak flow, will be the basis of the design capacity requirements for the reclaimed water reservoir or the injection well(s). The DOH may consider the historical flow records as a substitute for the peak flow design standard requirements provided the records include extreme flow conditions encountered by the WWTP. Calculated peak flows as a result of equalization basins will also be considered.

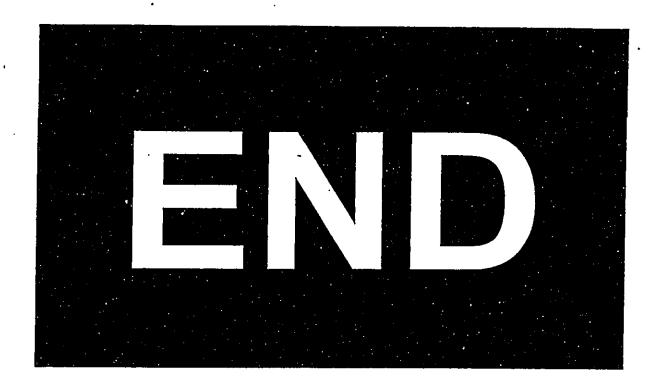
The application of the reservoir for reclaimed water reuse must satisfy the DOH's requirements outlined in Chapter 11-62 and the Guidelines for the Treatment and Use of Reclaimed Water. A backup injection well is not required if a reservoir design satisfies the capacity requirement; however, the County is still responsible for compliance if the reservoir overflows. We also agree with the construction of an effluent equalization reservoir to retain the effluent before discharging to the well(s) at a controlled rate.

Should you have any questions, please contact our Wastewater Branch at 586-4294.

Sincerely,

DENNIS TULANG, P.E. Chief, Wastewater Branch

PM:erm



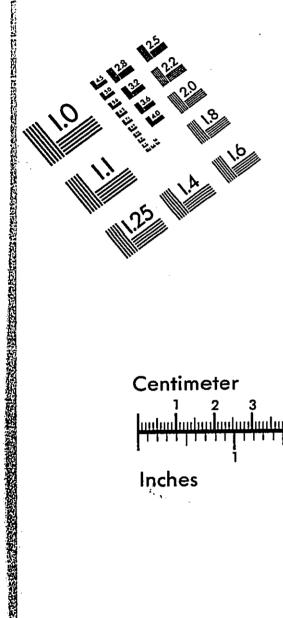
CERTIFICATION

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2004

DATE

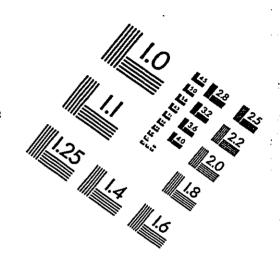
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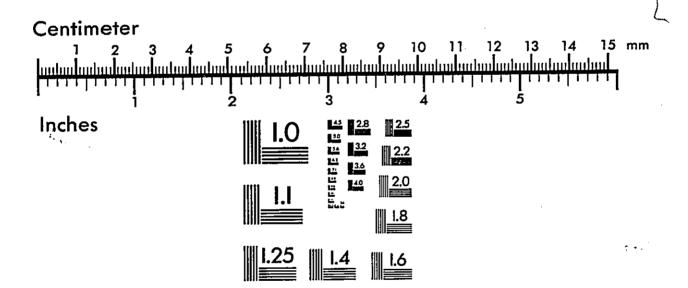


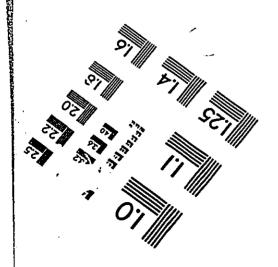


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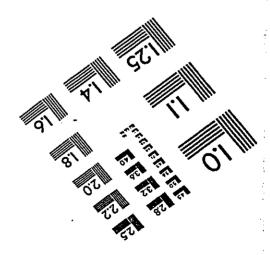
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